Germination and Establishment of Fourwing Saltbush in the Southwest

by
H. W. SPRINGFIELD

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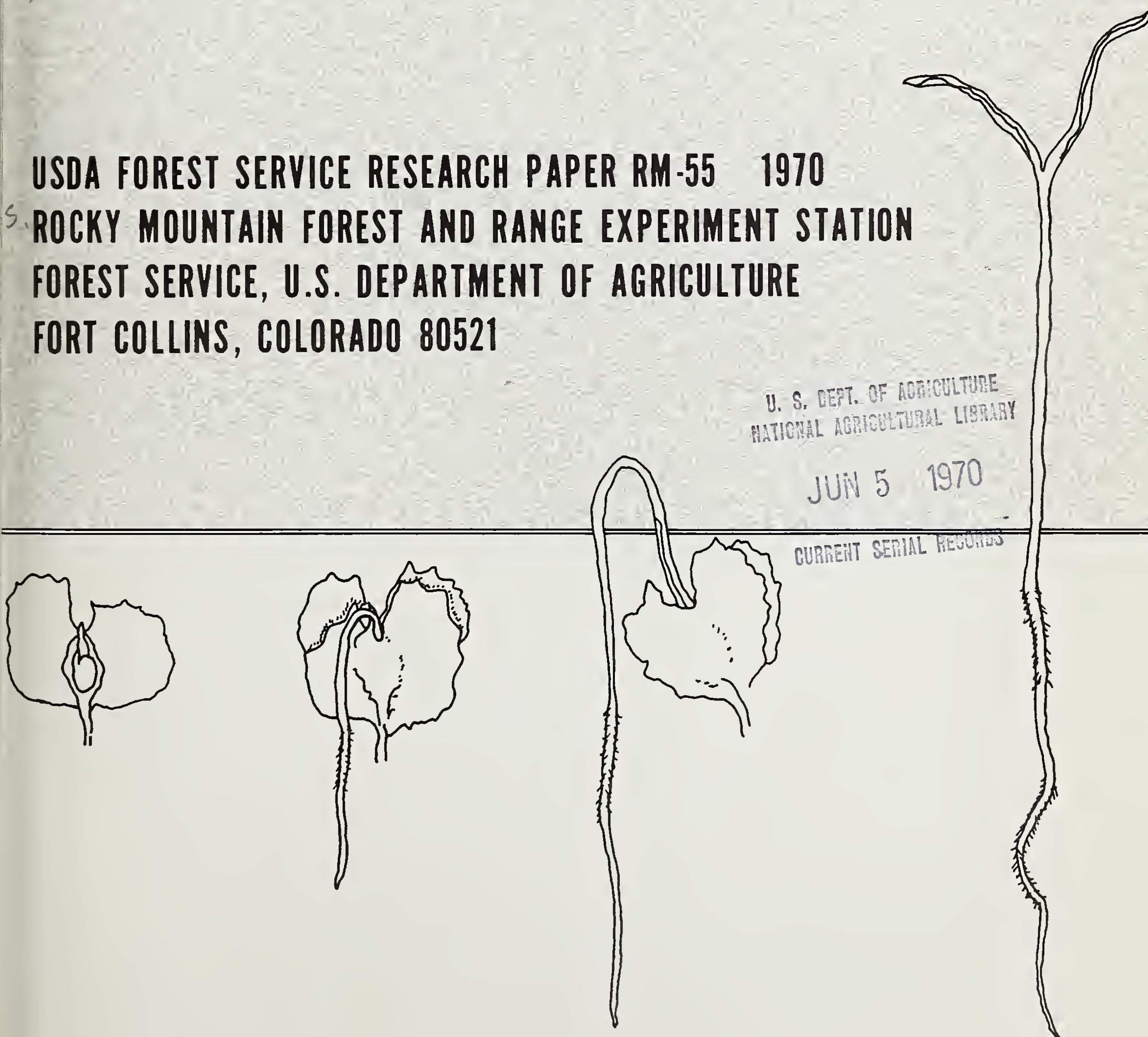

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by

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H. W. Springfield

PURPOSE OF THE STUDY

Fourwing saltbush (Atriplex canescens (Pursh) Nutt.)[2] is one of the most important shrubs on western ranges. Widely distributed, this plant furnishes forage for livestock and wildlife in all seasons; it is especially valuable as browse on winter ranges. Also known as chamiza in the Southwest, and as buckwheat shrub, white greasewood, saltsage, bushy atriplex, and wafer sagebrush elsewhere, fourwing saltbush derives its most common name from the characteristic four-winged fruit. Its importance is due to abundance, accessibility, size, large volume of forage, evergreen habit, high palatability, and nutritive value (U. S. Forest Service 1937). Nearly 70 years ago, Smith (1900) recommended this species for cultivation because of its high nutritive value and growth on poor and salty soils.

Through the years, fourwing saltbush has been seeded numerous times by ranchers and public agencies. Some seedings were successful, but many of them failed. Poor seedbed preparation, wrong time of seeding, and destruction by rabbits or rodents have been offered as explanations for the seeding failures. Recent investigations indicate many different factors influence the germination and establishment of fourwing saltbush. The results of a variety of experiments are summarized in this report. The information should be useful to anyone planning to revegetate ranges with fourwing saltbush.

DISTRIBUTION AND GENERAL CHARACTERISTICS

Fourwing saltbush grows from eastern Oregon to North Dakota and southward to Mexico, and is common in central and southern Nevada, Utah, Arizona, New Mexico, the Mojave and Colorado Deserts of California, western Texas, and northern Mexico. A. canescens is one of the most widely distributed species of Atriplex in the United States (Bidwell and Wooten 1925, Dayton 1931).

It is a common plant of dry, moderately saline sites in the plains, foothills, and intermountain valleys of the creosotebush, sagebrush, desert grassland, oak woodland, and pinyon-juniper types. Sometimes it is the dominant species over extensive areas, but more often it grows mixed with other shrubs, grasses, and forbs.

Plants grow naturally under a variety of soil and climatic conditions. It is found on sand dunes, alluvial flood plains, gravelly washes, mesas, ridges, and slopes. Usually it is most vigorous in sandy loam or loam soils, but plants will grow in clay soils. It tolerates salinity, but is not restricted to saline soils (U. S. Forest Service 1937). Wilson (1928) reported it does not grow naturally on noncalcareous soils.

Roots of mature plants will reach depths of 5 to 15 meters (m.) in alluvial soils. Its extensive root system makes the plant remarkably drought resistant (Van Dersal 1938).

Fourwing saltbush is medium sized, grayish white, and evergreen (fig. 1). Ordinarily, mature plants are 1 to 2 m. tall. Plants branch freely from the ground surface; the woody branches are rigid and rather brittle. Bark of the older branches is roughened by small longitudinal fissures and exfoliates. The leaves, pale grayish green, thick, glabrous, alternate, and often clustered, are mostly 2 to 5 cm. long and 2 to 7 mm. wide. Though the plant is classed as an evergreen, many leaves are dropped each year, especially during winter at the higher elevations. Staminate and pistillate flowers are on different plants. The nonshowy, small, greenish-yellow flowers form in panicles at the ends of young stems during summer. Characteristic four-

[2] *Common and botanical names of plants associated with fourwing saltbush are listed on page 48.*

Figure 1.--Vigorous, productive, fourwing saltbush near Isleta, New Mexico.

winged fruits develop gradually through the summer, turn yellow, and ripen in the fall. The fruit is dispersed by wind and gravity. Seed-bearing age ordinarily is 2 to 4 years, but 1-year-old plants have produced seed (fig. 2).

One of the most palatable of southwestern shrubs, the leaves, stems, and fruits of fourwing saltbush are cropped by all classes of livestock. Horses and deer browse fourwing saltbush mainly during the winter (Judd 1962). Scaled quail utilize the plant for shade, cover, roosting, and food (Van Dersal 1938). Burnham and Johnson (1950) recommend it for quail cover in New Mexico. Its forage value is almost legendary; a large number of references testify to its nutritive quality and usefulness (Dayton 1931 , Bridges 1942, Benson and Darrow 1944, Cook et al. 1954). The plants are relatively high in crude protein, calcium, and phosphorus throughout the year, as shown by these analyses of samples from central New Mexico (Watkins 1943):

	Crude protein	Calcium	Phosphorus
	- - -	(Percent) -	- -
March	10.0	1.5	0.09
June	15.8	1.3	.20
September	13.5	1.4	.15
December	11.1	1.0	.12

Bidwell and Wooten (1925) reported protein contents of 14 to 18 percent for samples collected in midwinter. Cattle have been held exclusively on fourwing saltbush areas for 9.5 months to demonstrate its value as an emergency feed (Foster et al. 1921). Costello (1944) reported cattle gained more on pastures where there were fourwing saltbush plants. Saltbushes are classed as secondary selenium absorbers in that the plants will accumulate this element on selenium-bearing soils (Schmutz et al. 1968).

Figure 2.--This plant established at Santa Fe, New Mexico, by direct seeding in August 1967 produced seed in September 1968.

METHODS OF STUDY

Seed germination and seedling characteristics were studied mainly in a laboratory and nursery at Santa Fe, New Mexico.[3] Methods of establishment and adaptability were studied at several representative sites (table 1).[4]

Seed germination studies were conducted in a standard Da-Lite (Stults Scientific) germinator[5] equipped to control temperature (55° to 90° [6]) and light, a Mangelsdorf germinator with temperature (70° to 110°) controls only, and a refrigerator modified to furnish temperature regimes within the range of 35° to 70° with or without light. All tests were made in petri dishes or small plastic boxes. Various substrata were tried, but vermiculite was the most commonly used substratum.

Seedling characteristics were studied in a plastic greenhouse and lathhouse. Most of the studies were set up in nursery flats containing plant bands (fig. 3). Different soils and horticultural mixes were used. Seeds were sown directly into the plant bands. Other studies were conducted in 1-quart to 1-gallon containers filled with soil from a representative site or with mixtures of soil, sand, and vermiculite.

Adaptability to different climates and soils was studied by using transplants, which were planted at several representative sites. These plants were grown from seeds collected at a variety of sites,

[3] *These studies were conducted in cooperation with the New Mexico Department of Game and Fish under the Federal Aid to Wildlife Restoration Act, Pittman-Robertson Research Project W-109-R-3, "Range Revegetation Investigations."*

[4] *Field studies were made mostly on National Forests in cooperation with the Southwestern Region of the U. S. Forest Service, Albuquerque, New Mexico.*

[5] *Trade names and company names are used for the benefit of the reader and do not imply endorsement or preferential treatment by the U. S. Department of Agriculture.*

[6] *All temperatures are given in Fahrenheit degrees.*

Figure 3.--Seedling characteristics were investigated through studies in nursery flats containing plant bands.

Table 1.--Description of sites in New Mexico where establishment and adaptability of fourwing saltbush were studied

Study site	Elevation	Precipitation		Length of growing season	Soil texture	Principal understory plants
		Annual	October through March			
	Feet	Inches	Percent	Days		
Corona	6,300	15	30	175	Sandy loam	Blue grama, western wheatgrass
Fort Bayard	6,300	14	33	194	Clay loam	Blue grama, side-oats grama
Glorieta Mesa (near Pecos)	7,200	15	29	140	Loam	Blue grama, western wheatgrass
Monica (near Magdalena)	7,500	12	31	123	Sandy loam	Blue grama, ring muhly
Quail Restoration Area (QRA) (near Santa Fe)	6,400	12	33	160	Sandy loam	Blue grama, galleta
Silver Hill (near Magdalena)	6,900	11	31	135	Loamy sand	Blue grama, sand dropseed
Taos Junction (near Tres Piedras)	7,200	13	37	146	Sandy loam	Big sagebrush, blue grama
Wingate (near Gallup)	7,400	12	34	125	Clay	Blue grama, western wheatgrass

principally in Arizona and New Mexico. The plants probably constitute different geographic strains or ecotypes with different site requirements.

Methods of establishment were investigated through hand trials and mechanized seeding tests at several field sites. These involved comparisons between different methods of seedbed preparation and seeding. Seedling emergence and survival, and plant establishment and growth were recorded.

RESULTS AND DISCUSSION

Seed Characteristics

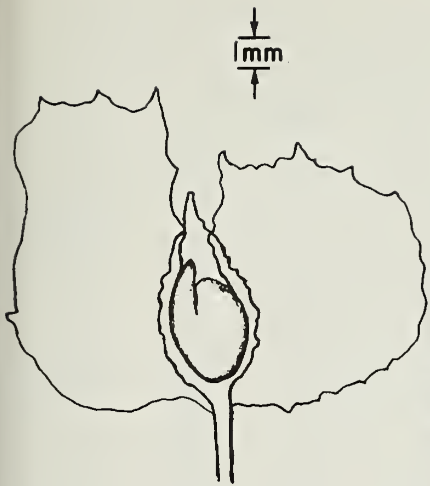
What we commonly refer to as the seed of fourwing saltbush is actually the fruit. Known to botanists as a utricle, the fruit is indurate and thick walled. The true seed, which measures only 1 to 3 mm. long, is enclosed within the fruit (fig. 4). Because of the difficulty of extracting the true seeds, fruits were used in all our investigations. Throughout this report, fruits will be considered as seeds.

Size of seed

Size of seed varies greatly from site to site, plant to plant, and even on the same plant. Length of seed for 117 collections ranged from 2.2 to 9.4 mm., and width of wings from 4.9 to 23.2 mm. Number of seeds per pound ranged from 7,800 to 54,900 for winged seed and from 13,200 to 76,800 for de-winged seed. According to the Woody Plant Seed Manual (U. S. Forest Service 1948), the average for winged seed is 22,500 per pound. Wilson (1928) reported there are 30,000-40,000 seeds per pound. Differences in size and number of seed per pound for eight collections in New Mexico and Arizona are given in table 2.

Seed fill

A high percentage of empty seeds apparently is characteristic of fourwing saltbush. Only slightly more than half of 16,000 seeds from 117 collections throughout Arizona and New Mexico contained



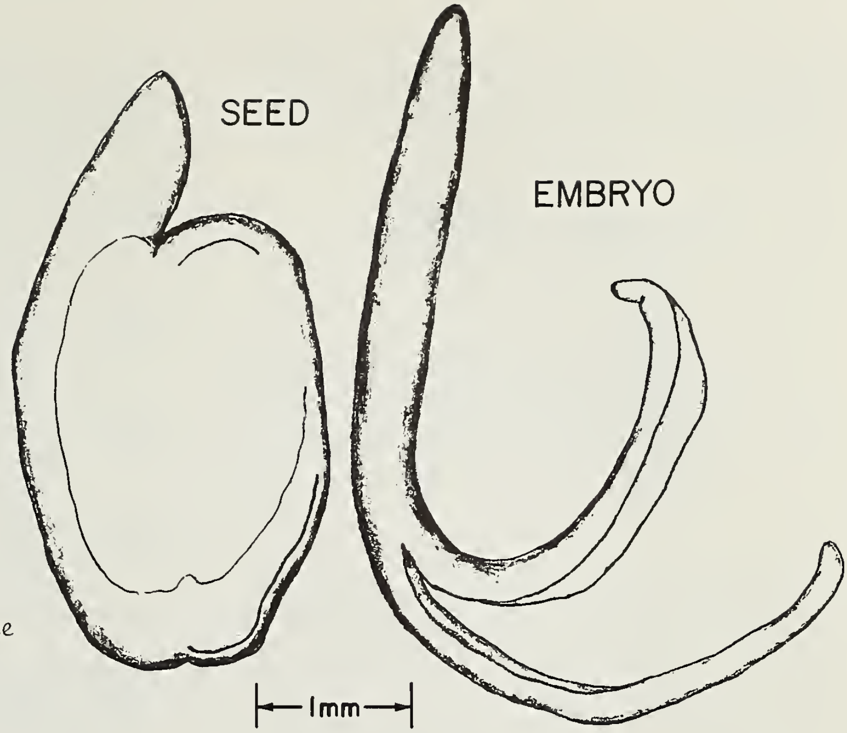


Figure 4.--Position of seed inside winged fruit. Tip of the radicle fits the thumblike protuberance on the seed. The embryo envelops the endosperm, which fills the central core of the seed.

Table 2.--Characteristics of fourwing saltbush seeds collected from eight sources in New Mexico and Arizona

Seed source	Characteristics of collection site			Size of seed		Seeds per pound	
	Geographic location	Elevation	Annual precipitation	Length	Width	Winged	De-winged
		Feet	Inches	Mm.	Mm.	Number	
NEW MEXICO:							
Isleta	1 mile east of Isleta	5,000	9	4.7	12.2	18,000	29,200
Mountainair	5 miles south of Mountainair	6,700	14	4.1	10.7	19,100	38,100
Corona	6 miles west of Corona	6,300	15	4.5	10.4	25,300	38,800
Monica	20 miles west of Magdalena	6,600	13	5.2	11.8	14,800	27,900
Glenwood	3 miles south of Glenwood	4,500	14	3.7	7.0	28,900	51,300
ARIZONA:							
Flagstaff	18 miles northwest of San Francisco Peaks	6,500	17	2.8	8.7	34,000	58,100
Beaver Creek	3 miles southeast of Camp Verde	3,500	14	3.5	9.0	26,600	53,800
Chevelon	30 miles south of Winslow	6,200	15	4.6	13.1	17,500	31,100

embryas. The average was 53.6 percent filled. Two-thirds af the callectians had less than 60 percent filled:

Percent fill	Number of collections
1-10	1
11-20	3
21-30	7
31-40	14
41-50	24
51-60	26
61-70	19
71-80	16
81-90	5
91-100	2

Na relatianship was faund between percentage af filled seed and elevatian af the callectian site. Elevatians ranged fram 1,400 to 7,800 feet; most were fram 4,000 ta 7,000 feet.

Percentage af filled seed generally was higher far the larger seeds (table 3). The prapartian af seeds cantaining embryas was highest for seeds classed as large in 105 af the 117 callectians. Year af callectian anly slightly affected the averall average fill percentages.

Source af seed alsa is a factar (table 4). Far example, seeds classed as small in the Caballo callectian were langer and wider than those classed as large in the Saffard collectian; still, all sizes af the Saffard seeds were better filled than the Caballa seeds.

Table 3.--Percentage of filled fourwing saltbush seeds of different relative sizes collected, 1960-64

Year of collection	Average filled seeds, by relative size			
	Large	Medium	Small	Average
	- - - Percent - - -			
1960	59.3	57.0	53.3	56.5
1961	57.6	52.7	40.8	50.4
1962	61.8	52.0	45.5	53.1
1963	66.5	59.4	43.8	56.6
1964	61.8	50.2	41.5	51.2
Average	61.4	54.3	45.0	53.6

Table 4.--Relation of size of fourwing saltbush seeds to percent of filled seeds from three collection sites

Seed source	Relative size of seed	Length of seed	Width of wings	Filled seeds
		- - Mm.	- -	Percent
Isleta	Large	5.5	14.8	94
	Medium	4.8	11.5	91
	Small	3.9	9.5	91
Caballo	Large	7.2	23.2	53
	Medium	6.1	18.2	25
	Small	5.2	14.0	12
Safford	Large	4.8	10.6	82
	Medium	3.8	8.2	75
	Small	3.2	6.5	65

Table 5.--Percentage of filled fourwing saltbush seeds collected for 5 years from the same plants at four sites in New Mexico

Seed source	Elevation	Filled seeds, by year of seed collection				
		1961	1963	1964	1965	1966
	Feet	- - - Percent - - -				
Corona	6,500	67	51	20	36	25
Isleta	4,900	92	86	92	91	76
Deming	4,300	78	30	59	61	57
Hatch	4,100	41	58	58	39	([1])

[1]Plants destroyed.

The only twa callections with mare than 90 percent fill were from a single plant near Isleta. Seeds fram this particular plant cansistently have had a higher fill than seeds from ather saurces (table 5), which suggests percent fill may be gaverned primarily by genetic factors, ar passibly by site factors. Data for the ather sources, hawever, indicate year-ta-year variatians in weather or other envirannental factars, including prevailing winds, prabably are impartant, taa.

Germinatian data available for seeds from 52 af the callectians indicate that fill accaunted far 68 percent of the variatian in germinatian ($R = 0.825$, fig. 5).

Cutting tests are recommended an samples of seed sa that seeding rates can be adjusted for what

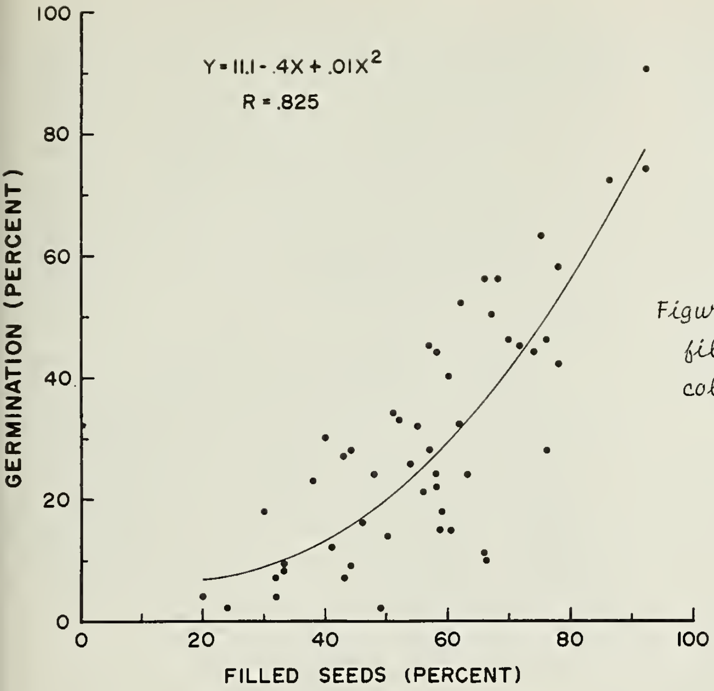


Figure 5.--Relationship between percentage of filled seeds and germination for 52 collections of fourwing saltbush seeds.

very likely will be a high percentage of empty seeds. Fill percentages of less than 40 should be considered substandard. If the smaller seeds have appreciably less fill than the larger seeds, they could be screened out and discarded to improve the efficiency of seeding operations.

Although percent fill probably is partly genetic, information obtained indicates environmental factors also are important. Perhaps seed fill could be improved through cultural practices such as cultivation, irrigation, or fertilization.

Seed Collection and Processing

The seeds are easily collected when they are fully mature. Maturity or ripeness is mainly reflected in color and dryness. Mature seeds usually are a yellow or yellowish orange, and practically air dry. They can be stripped from the branches by hand with little difficulty, and collected in bags, baskets, or on a canvas spread out around the bush. Seeds are sometimes collected with a vacuum-type seed harvester developed by the U.S. Forest Service Equipment Development Center.

To reduce bulk and facilitate handling and seeding, the winged seeds usually are hammermilled. The seeds may be further cleaned in a fanning mill to remove chaff and other debris. Records of Region 3, U.S. Forest Service, showed that 6,181 pounds of winged seed collected in five areas yielded 2,588 pounds of clean, de-winged seed. Hammermilling and cleaning thus reduced the weight by more than 50 percent.

Time of Seed Collection

Time of seed collection could be an important factor affecting germination. An error in judging maturity might result in the collection of immature seeds. Since seeds of fourwing saltbush commonly remain on the bushes from October to April in the Southwest, they can be collected over a period of several months.

Seeds collected from a plant at the Silver Hill site in November 1964 germinated 23 percent in July 1965, whereas seeds collected from the same plant in March 1965 germinated only 10 percent. Similar studies in July 1966 gave different results:

	Collection date	Germination at 66°
Silver Hill	November 17, 1965	33
	April 19, 1966	59
Isleta	December 30, 1965	85
	April 19, 1966	84

The Silver Hill seeds were collected from the same plant as in 1964-65, yet germination was decidedly different; seeds collected in April 1966 germinated appreciably better than those collected in March 1965. The Isleta seeds were collected from the same plant on both dates, and germination of the two collections was nearly identical. Delaying collection of the 1965 crop until April 1966 certainly was not disadvantageous.

Delay in collection of the 1966 seed crop from the plant at Isleta, however, resulted in lower germination. October-collected seeds germinated significantly better than March-collected seeds:

Date seed collected	Date of test: April 1967	July 1967	July 1968
	(Percent germination)		
1966:			
October 26	74	86	87
December 30	35	70	81
1967:			
January 27	24	48	82
March 7	20	35	63

Of interest is the improvement in germination with time. By July 1968, germination was about the same whether seeds were collected in October, December, or January.

Afterripening

Seeds of fourwing saltbush apparently undergo afterripening. This process, which usually involves chemical changes that remove germination blocks, may require hours, days, weeks, or months depending on the seed (Pollock and Toole 1961). Seeds of many species are dormant or resting at the time of maturity. They will not germinate, even with favorable moisture and temperature, until they undergo afterripening. Fourwing saltbush seeds frequently have germinated better the second or third year after collection than during the first year.

The afterripening process, for fall-collected fourwing saltbush seeds, appears to be essentially complete in about 10 months. Seeds collected October 23, 1967 from one plant at Isleta were tested at 2-week intervals for a year. Germination patterns were erratic. Germination on the 10th day—a good measure of seed vitality—improved gradually as the seeds aged. When the seeds were 22 weeks old, germination reached a peak, then gradually declined. This peak corresponds to the time of year (late March) when young saltbush seedlings have been observed emerging in nature. This finding supports the idea held by some physiologists that seeds contain built-in "time clocks." Another peak was reached by seeds 38 weeks old, then germination declined, gradually increased, and finally leveled off for seeds 46 to 52 weeks old. Trends in 30-day germination, the more conventional measure of seed viability, generally parallel those of 10-day germination.

Seeds that have essentially completed the afterripening process also germinate more rapidly than freshly collected seeds (fig. 6). When tested only 8 weeks after collection, seeds germinated very slowly; germination was negligible the first 20 days. By contrast, seeds tested 44 weeks after collection germinated rapidly; germination was practically complete in 15 days.

Germination

Imbibition

The uptake of water by the seed, known as imbibition, is the first process that occurs during germination. Composition of the seed, permeability of the seed or fruitcoat to water, and availability of water influence the extent of imbibition.

Our studies show winged seeds of fourwing saltbush are fully imbibed in about 24 hours (fig. 7). Air-dry seeds with wings increased 92 percent in weight when fully imbibed.

De-winged seed imbibed water more rapidly than winged seed and were practically fully imbibed in about 15 hours, at which time they had increased in weight 59 percent.

These results suggest that, when the soil becomes wet, the seeds will imbibe and the germination process can start in 1 day, contingent of course on other environmental factors.

Temperature Effects

Fourwing saltbush seed usually germinates best at relatively low temperatures. The Woody Plant Seed Manual (U.S. Forest Service 1948) recommends testing germination at 77° (day) and 50° (night) for 20 to 30 days. Wilson (1931) reported seeds germi-

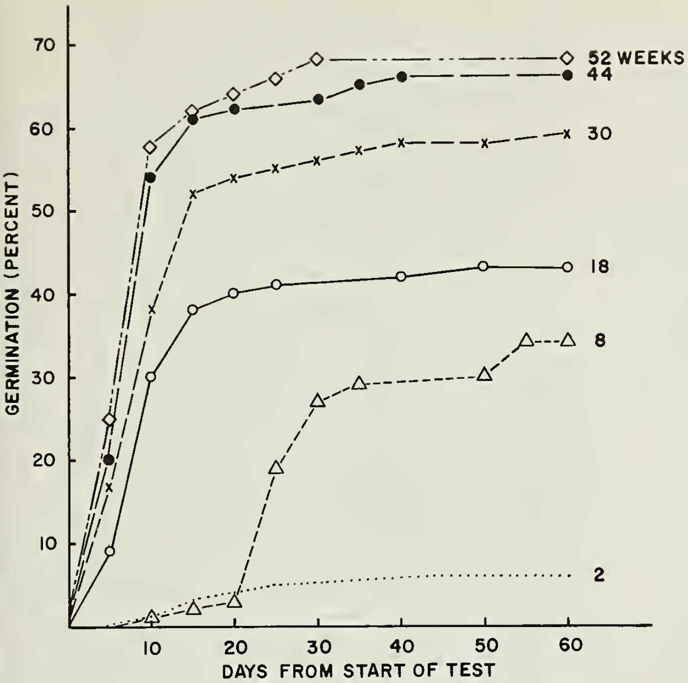


Figure 6.--Afterripening illustrated by germination rates in tests begun 2, 8, 18, 30, 44, and 52 weeks from the date seeds were collected.

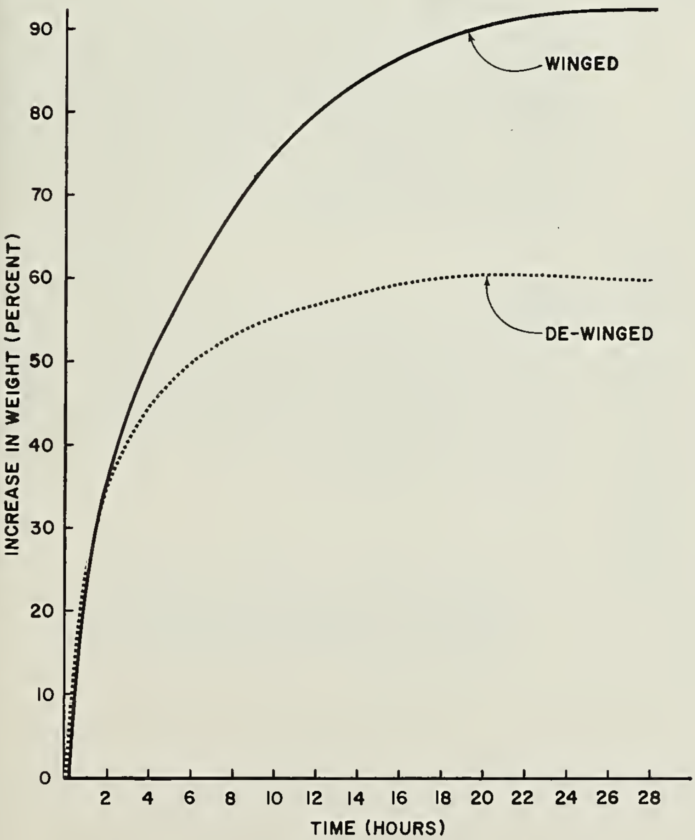


Figure 7.--Imbibition of winged and de-winged fruits of fourwing saltbush (average of four sources--fruits air dry--74°).

nate in the field during cool or cold weather. In Australia, Knowles and Condon (1951) found cool, wet weather was conducive to germination of Atriplex vesicarium, a perennial saltbush. They reported germination seldom is good after summer rains because of high temperatures. Beadle (1952) found the optimum temperatures for five species of Atriplex in Australia fell between 59° and 77°. In Colorado, Hervey (1955) obtained 47 percent germination of fourwing saltbush at 68°, 45 percent at 59°, and 7 percent at 39°. Gerard (1965) reported 55° to 85° as the optimum temperature range for germination of fourwing saltbush seeds collected in southern New Mexico. He obtained highest germination at constant temperatures of 55°, 65°, and 85° and alternating temperatures of 70° (10 hours) and 60° (14 hours).

In our studies, germination of eight sources of seed from Arizona and New Mexico was higher at constant temperatures of 42° and 58° than at 77° (Springfield 1964). Germination of all eight sources averaged significantly less at 77° (fig. 8). Improvement in percent germination at 58° compared with 77° was especially pronounced for the Corona, Glenwood, Flagstaff, and Beaver Creek seed. Though there was a trend toward higher germination at 58° than at 42°, the difference between average germination at these two temperatures was not significant.

Further studies with 15 sources of seed showed significantly higher germination at a constant temperature of 55° than at alternating temperatures of 86° (8 hours, light)-68° (16 hours, dark). All sources germinated better at the lower temperature.

Intensive investigations with seeds collected from a single plant near Isleta, New Mexico, revealed optimum temperatures for germination were from 55° to 75° (fig. 9). Germination in 30 days was appreciably less at temperatures from 39° to 55° or from 75° to 100°. For the comparisons, alternating temperatures are expressed as weighted mean temperature. Germination at weighted mean temperatures generally averaged less than at the corresponding constant temperature. The higher temperature in the alternation, particularly temperatures exceeding 80°, apparently had a depressing effect on germination. The germination behavior at alternating temperatures seems to be related to the separate effects of the two component temperatures and the time of exposure to each, rather than to be a direct response to hour-degrees such as expressed by weighted mean temperature.

Seeds from the Isleta source began germinating within 2 days at a temperature of 81° and within 3 days at temperatures of 65° and 73° (fig. 10). Germination was nearly complete within 6 days at 65°, 73°, and 81°. At lower temperatures, the start of germination was delayed and the speed of germination was slower.

Moisture

As for all seeds, adequate moisture is essential for the germination of fourwing saltbush seeds. When temperatures are near optimum, however, saltbush seeds apparently will germinate under relatively high moisture stress.

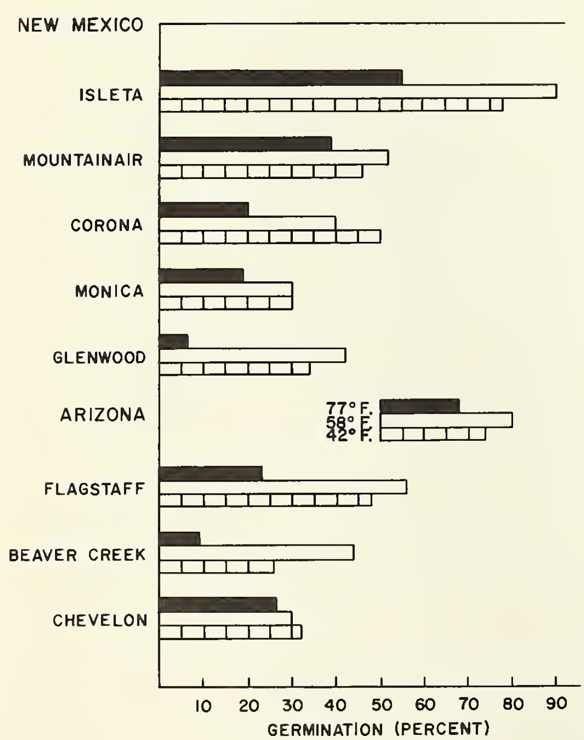


Figure 8.--Germination of eight sources of seed in 36 days at three constant temperatures.

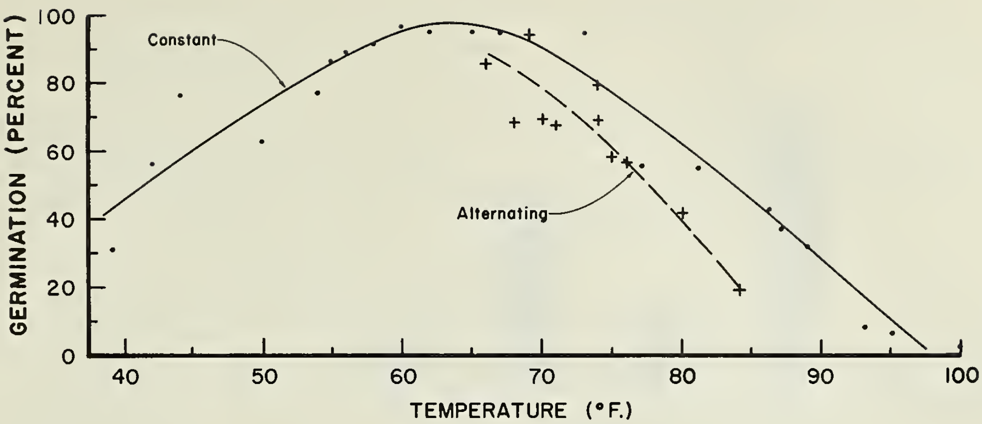


Figure 9.--Germination of Isleta fourwing saltbush seeds at constant and alternating temperatures in a 30-day period.

To determine the effects of moisture stress on the germination of six sources of seed, stresses were induced by different concentrations of mannitol (Springfield 1966).

Total germination decreased as moisture stress increased (fig. 11). Germination at 0.3 and 3 atmospheres (atm.) osmotic stress was greater than at 7, 11, or 15 atm. Isleta and Mountainair seeds germinated significantly better than seeds from the four other sources (table 6). The Mountainair source germinated better than the other sources at stresses of 11 and 15 atm.; seeds from this source may have characteristics that enable them to germinate and become established under relatively dry conditions.

Germination was also delayed by increasing moisture stress (fig. 12). Temperature strongly influenced these delays. Seeds tended to germinate better under the higher stresses at 63° than at 49° or 85°. Seeds germinated well even under the relatively high 7-atm. stress at 63°, which suggests moisture stress may be less important in the germination of saltbush seeds when temperatures are near optimum.

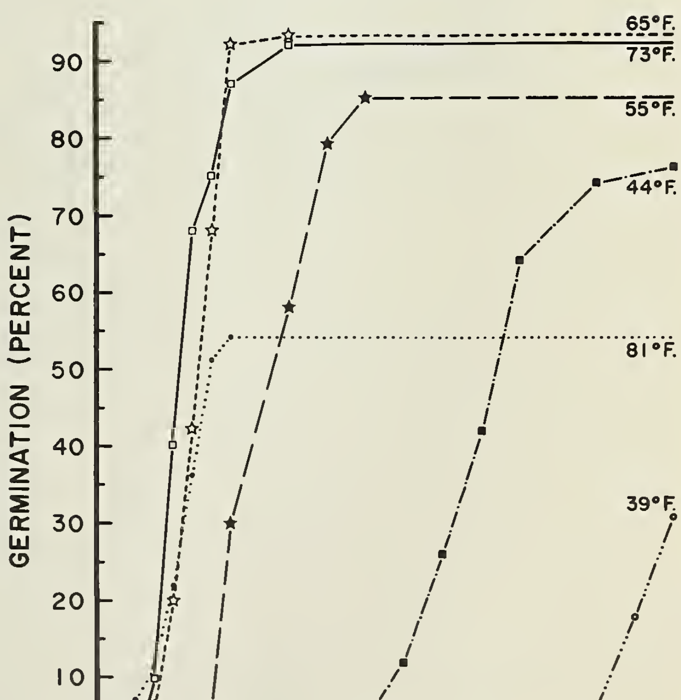


Figure 10.--Speed of germination of Isleta seeds at different constant temperatures.

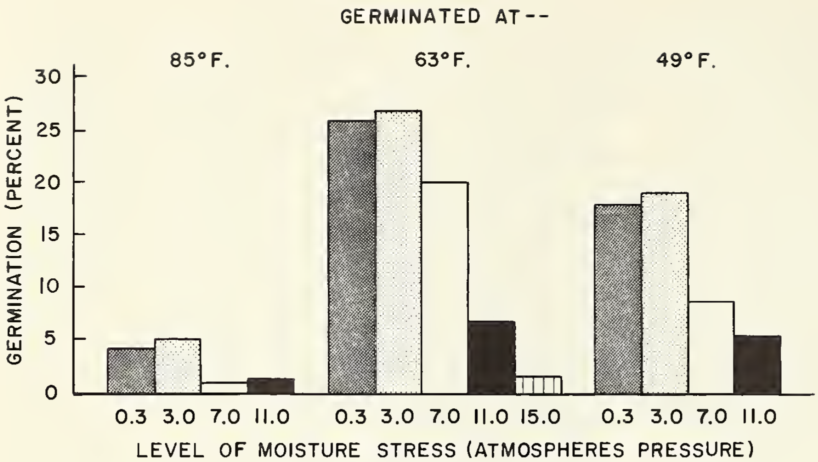


Figure 11.--Average germination of six seed sources at five moisture stresses.

Figure 12.--Speed of germination at different moisture stresses and temperatures.

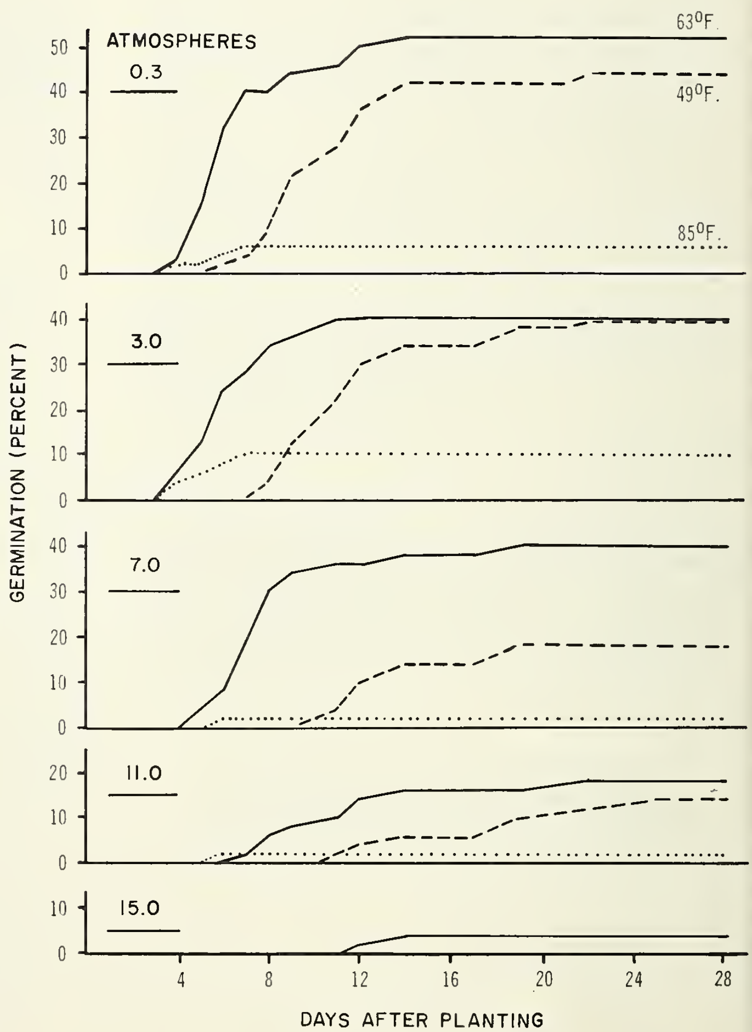


Table 6.--Average percentage of fourwing saltbush seeds that germinated at 63° and 49° at five levels of moisture stress (seed collected from six sources)

Seed source	Germination by levels of moisture stress					
	0.3 atm.	3 atm.	7 atm.	11 atm.	15 atm.	Average[1]
	Percent germination					
Isleta	60	48	28	12	0	29.6a
Mountainair	34	32	30	20	4	24.0a
Corona	6	12	8	0	0	5.2b
Chevelon	8	24	12	0	0	8.8b
Beaver Creek	16	20	4	6	0	9.2b
Glenwood	8	4	4	0	0	3.2b
Average[1]	22.0a	23.3a	14.3b	6.3c	0.7d	

[1]Values followed by the same letter do not differ significantly at the 0.05 level using Duncan's multiple range test.

Table 7.--Average percentage of fourwing saltbush seeds that germinated in 30 days in periods of continuous darkness and various photoperiods (seeds collected from three sources)

Temperature (°F.)	Daily light	Germination by seed source and collection date			
		San Juan 1963 seed	Isleta 1963 seed	Isleta 1966 seed	Average
	Hours	Percent			
Constant:					
63°	24	55	93	59	69
	0	63	90	49	67
73°	24	53	93	41	62
	0	52	89	29	57
81°	24	41	54	39	45
	0	37	56	15	36
86°	24	23	34	16	24
	0	7	28	3	13
Alternating:					
76° for 12 hours - 62° for 12 hours	12	61	92	75	76
(Average 69°)	0	67	89	67	74
92° for 10 hours - 72° for 14 hours	10	18	41	15	25
(Average 80°)	0	11	16	7	11

Light

Light apparently neither inhibits, nor is required for, germination of fourwing saltbush seeds. Seeds have germinated practically the same in continuous light as in continuous darkness. A source from Continental, Arizona, for example, germinated 21 percent in continuous light and 24 percent in continuous darkness.

Intensive investigations, however, showed some differences in the germination of three sources of seed under various light and dark situations (table 7). Three-year-old seeds held in continuous darkness germinated nearly as well as those exposed to continuous light at constant temperatures of 63°, 73°, and 81°, and at alternating temperatures of 76° (12 hours)-62° (12 hours) with 12 hours of light during the 76° temperature period. Seeds less than 4 months old (collected October 26, 1966, and tested in February 1967), however, germinated less when held in continuous darkness under all temperatures. At 92° (10 hours)-72° (14 hours), all three sources of seed germinated less when held in darkness than when exposed to 10 hours of light daily. Source of light was cool white fluorescent bulbs except at the constant 81°, when Gro-lux bulbs rich in red and blue light were used.

These results indicate light may be required for the germination of freshly collected seed regardless of temperature, and possibly also for older seed when the temperatures are relatively high. How old seeds must be before they no longer require light for germination when temperatures are near optimum is not known for sure, but the available evidence indicates seeds collected in the fall germinate satisfactorily in total darkness the next summer.

Aeration

Fourwing saltbush seeds apparently are sensitive to deficient aeration. No seeds germinated in saturated sand, compared with 51 percent germination in sand three-fourths saturated, and 64 percent in sand half saturated. The failure of seeds to germinate in saturated sand is attributed to deficient aeration. Minimal or optimal levels of oxygen required for germination have not been determined. Germination in 72 hours was significantly reduced when oxygen was held at slightly less than 5 percent (Lavin et al. 1968).

Factors Affecting Viability of Seed

Storage of Seed

Little information is available concerning proper storage of fourwing saltbush seed. The U.S. Forest Service (1948) recommended storing the seed in a dry place, and reported the seeds do not deteriorate appreciably, at least not until the 6th or 7th year after gathering; one lot germinated 19 percent after 9 years in dry, open storage. Hervey (1955) re-

Table 8.--Average percentage of fourwing saltbush seeds that germinated in 33 days, after 3-years' storage, refrigerated seed compared with unrefrigerated seed (seed collected from four sources)

Seed source	Year collected	Unrefrigerated 55° to 90°		Refrigerated 38° to 42°	
		Germination at--		Germination at--	
		Alternating 86°, 68°	Constant 54°	Alternating 86°, 68°	Constant 54°
		- - - - - Percent - - - - -			
Isleta	1961	66	76	70	76
Mountainair	1961	46	60	40	44
Corona	1961	40	66	20	34
Bernalillo	1962	30	24	32	30
Average		45.5	56.5	40.5	46.0

ported no difference in germination of seeds stored for 3 years in sealed containers at 37° to 41°, or stored open or in sealed containers at room temperatures.

Storage at subfreezing temperatures (-5° to -9°) for 2 years at Santa Fe did not affect viability. Average germination of six collections of seed was the same whether they were stored in paper bags at 55° to 90° or in cans at subfreezing temperatures:

	55° to 90°	-5° to -9°
	(Percent germination)	
Seed source:		
Safford	17	22
Flagstaff	4	20
Espanola	5	8
Lamy	24	20
Isleta	64	69
Gran Quivira	44	21
Average	27	27

Refrigeration of seed for 3 years at temperatures from 38° to 42° had no significant effect on viability (table 8). The trend was toward higher germination of the unrefrigerated seeds.

Viability of seed has been maintained for 6 years under ordinary storage conditions. Seeds collected in 1961 and stored in paper bags at temperatures from 55° to 90° germinated as well in 1967 as in 1963 (table 9).

Table 9.--Average percentage of fourwing saltbush seeds that germinated 1963-67 (seed collected in 1961 and stored in paper bags at 55°-90° temperatures)

Year germination tested	Germination temperature (constant or alternating)	Average germination	
		Isleta	Corona
	°F.	Percent	
1963	42	56	50
	58	90	40
	77	55	20
1965	50	62	46
	78, 58	67	36
	86, 68	48	36
1966	78, 58	75	41
	86, 68	75	34
1967	64	79	47

Table 10.--Average percentage of fourwing saltbush seeds that germinated in 1968 at 56° from four sizes of seeds collected from one plant at Isleta in 1966 and 1967

Size of seed	Treatment	Germination of seed collected in--		
		1966	1967	Average
		- - Percent - -		
Large	Winged	85.3	84.0	84.6
	De-winged	85.3	85.3	85.3
Medium	Winged	80.0	84.0	82.0
	De-winged	84.0	81.3	82.6
Small	Winged	81.3	89.3	85.3
	De-winged	88.0	84.0	86.0
Very small	Winged	84.0	81.3	82.6
	De-winged	80.0	77.3	78.6

Age and Size of Seed

Fourwing saltbush seeds retain their viability for many years. Some lost only about half their germinative energy in 16 years. These seeds, collected in October 1951 near Fort Collins, Colorado, germinated 20 percent the first year (Hervey 1955). Three years later, the seeds germinated 24 percent; tests indicated a potential germination of 32 percent. In November 1968, these seeds—stored at room temperatures—germinated 10 percent. Tetrazolium tests indicated a potential germination of 24 percent. Thus, the potential germination declined only one-fifth although the actual germination dropped one-half during the 16 years.

Size of seed does not appear to be an important factor provided the seeds are well filled. Four sizes of seeds from the plant at Isleta germinated about the same (table 10).

Effect of Year of Collection on Seed Viability

Seed viability varies with year of collection. Many factors undoubtedly affect the viability of each year's seed crop: age of the plants, proximity and ratio of male to female plants, moisture and temperature conditions during flowering and seed formation, wind movement, and insects.

Collections from the same individual plants at two sites for 4 years showed seeds from the plant near Isleta consistently had a high germination percentage whereas those from the plant near Corona gave erratic results. Average germination in 1966 at alternating temperatures, 78° (12 hours) - 58° (12 hours), was:

	Isleta	Corona
	(Percent	germination)
Seed collected:		
1961	75.3	41.3
1963	68.7	8.0
1964	66.0	3.3
1965	62.7	6.7
Average	68.2	14.8

This suggests the Isleta plant may represent a geographic or ecotypic strain with above-average seed viability.

Seed Treatments

De-winging the seed.—Removing the wings from the seed is an accepted practice. Advantages of de-winging are (1) ease of handling, especially when seeds are to be planted with a drill or other mechanical seeder, (2) reduction in bulk, and (3) easier coverage with soil. The usual procedure is to run the winged seeds through a hammermill.

De-winging the seed did not significantly affect final germination percentages. For all studies conducted from 1963 to 1968, winged seeds germinated 54 percent compared with 58 percent for de-winged seeds. In a study of eight sources of seed germinated at three temperatures, no significant difference was found in germination between winged and de-winged seed (table 11). Of the eight sources, only the de-winged Monica seed showed consistently higher germination. The de-winged seed germinated more quickly, however (fig. 13). Under temperatures of 77° and 58°, more than twice as many de-winged as winged seed had germinated by the 6th day. But by the 10th day at 77° and by the 24th day at 58° germination of the winged seed practically equaled that of the de-winged seed. This faster germination of de-winged seed may be desirable because favorable combinations of temperature and soil moisture are usually of short duration on southwestern ranges.

Additional studies showed de-winging the seed by hand or cleaner, as well as by hammermill, does not affect total germination. Seeds from Navajo Canyon, in northwestern New Mexico, were processed several ways; results of germination tests

Table 11.--Average percentage of winged and de-winged fourwing saltbush seeds that germinated in 36 days at three constant temperatures (seed collected from eight sources)

Seed source	Germination at constant temperature of--					
	76.6°		57.6°		41.8°	
	Winged	De-winged	Winged	De-winged	Winged	De-winged
	Percent					
Isleta	60	50	92	88	76	80
Mountainair	36	42	48	56	60	32
Corona	14	26	40	40	44	56
Monica	12	26	12	48	24	36
Glenwood	10	2	40	44	32	36
Flagstaff	26	20	48	64	44	52
Beaver Creek	6	12	48	40	28	24
Chevelon	22	30	44	16	32	32
Average	23.3	26.0	46.5	49.5	42.0	43.0

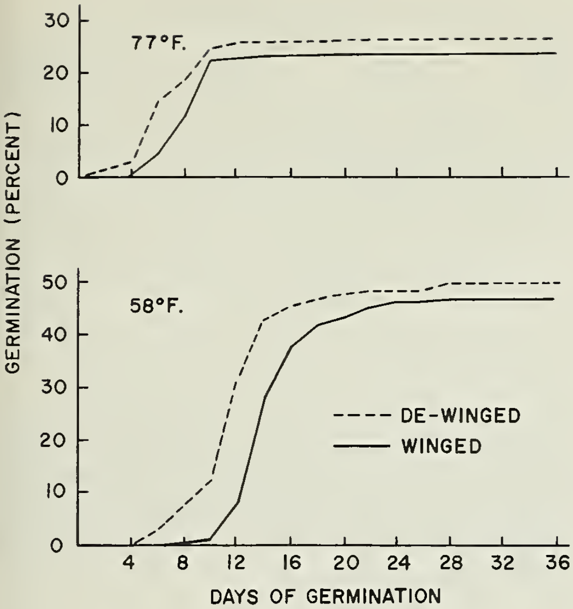


Figure 13.--Average germination rate of winged and de-winged fourwing saltbush seed from eight collection sites, at two temperatures.

under alternating temperatures of 86° (8 hours, light)-68° (16 hours, dark) were as follows:

	Percent
Winged seed	25.6
De-winged by:	
Handrubbing	26.0
Hammermilling	22.4
Dybvig cleaner	27.6

The differences in germination were not significant.

These findings are in accord with Hervey (1955), who reported 17 percent germination for hammermilled seed compared with 20 percent for winged seed.

Scarification.—Scarification of the seedcoats has not consistently improved the germination of fourwing saltbush in our studies, which does not agree with results reported from California (Nord and Whitacre 1957) where heavy scarification increased germination substantially.

Investigators who reported improved germination from de-winging or scarification have used hand treatments, in which seeds were rubbed between layers of sandpaper (Gerard 1965, Nord and Whitacre 1957).

In preliminary studies, we compared mechanical treatments with various hand treatments. Seeds collected in 1963 from Isleta and Lamy were planted in nursery flats. Percent germination from various seed treatments was as follows:

	Isleta	Lamy
	(Percent germination)	
Seed treatment:		
Not treated (winged)	41	48
Hand treated--		
De-winged	56	46
Rubbed	46	37
Scarified	11	52
Mechanically treated--		
De-winged	7	2
Scarified	0	0

Hand de-winging improved germination of the Isleta seeds, which agrees with Gerard's (1965) results, but did not affect germination of the Lamy seeds. Hand scarification was detrimental to the Isleta seeds; seeds of this source have relatively thin-walled seedcoats, so they may have been over-scarified. Hand rubbing (between gloves) removed most of the wings but did not scratch the seedcoat; yet this treatment lowered the germination of Lamy seed, perhaps by damaging the embryo. Mechanical treatment was definitely detrimental.

Later, more intensive studies showed that effects of scarification vary with the source of seed and seedcoat characteristics. Seeds with moderately thin seedcoats were damaged by mechanical scarification with abrasives (table 12). Even light scarification was detrimental. On the other hand, seeds with thick seedcoats apparently were benefited by very light scarification. Our scarification treatments, performed in a small electric scarifier lined with sandpaper, may have been too severe for most seeds. Microscopic examination revealed many of the treated seeds had relatively large holes in the seedcoat; the percentage of such seeds increased with the number of seconds of scarification treatment.

Germination tests were made on seeds classified according to degree of seedcoat abrasion. Germination of the thinner walled seeds from Deming and Isleta was reduced significantly whenever scarification caused a break or hole in the seedcoat. By contrast, germination of the thicker walled seeds

Table 12.--Extent of scarification damage[1] to fourwing saltbush seeds, and resultant germination

Source of seed	Rating of seedcoat[2]		No treatment (control)		Scarification treatment									
					Very light (20)		Light (40)		Medium (60)		Heavy (80)		Very heavy (100)	
	Thick-ness	Hard-ness	Winged	De-winged	Seed-coat damage	Germi-nation	Seed-coat damage	Germi-nation	Seed-coat damage	Germi-nation	Seed-coat damage	Germi-nation	Seed-coat damage	Germi-nation
			Percent germination		- - -	- - -	- - -	- - -	Percent	- - -	- - -	- - -	- - -	- - -
Deming	2	3	70.7	61.0	18	32.3	32	23.0	38	7.7	44	9.3	54	4.0
Isleta	2	2	96.3	88.7	28	60.7	36	37.3	48	2.7	60	1.3	74	0
Madrid	4	3	53.3	65.0	2	83.7	16	34.7	30	32.7	58	23.0	50	23.0

[1]Percentage of seeds with large holes in seedcoat because of scarification treatment; numbers in parentheses indicate seconds in electric scarifier lined with sandpaper.
[2]Rating scale: Thickness-- 1 = thin, 4 = very thick Hardness-- 1 = hard, 4 = very hard.

from Madrid was not affected by small holes or breaks in the seedcoat. Seeds with large holes in the seedcoats gave negligible germination, however, regardless of source of seed and thickness of the seedcoat.

These results, coupled with results of other supplemental studies, suggest scarification should be used with caution. The proper degree of scarification could improve the germination of thick-walled seeds. Nevertheless, care should be taken to prevent overscarifying the seed to the point where large holes form in the seedcoat.

Chemical Treatment of Seeds

Various chemical treatments have been tried in an attempt to increase germination of fourwing saltbush seeds. None proved satisfactory.

Thiourea.—Universally used to stimulate seed germination, thiourea did not improve the germination of fourwing saltbush. In fact, results of our investigations indicate thiourea may inhibit germination of this species. Two sources of seed (San Juan and Deming) soaked 10 to 30 minutes in 3 percent thiourea germinated less than untreated seeds. Average germination of fourwing saltbush seed in 30 days at 86° (8 hours)-68° (16 hours) was:

	San Juan	Deming
	(Percent germination)	
Untreated	43	21
Seeds soaked in 3 percent thiourea:		
10 minutes	13	8
20 minutes	12	5
30 minutes	6	5

Soaking only 3 to 6 minutes proved less detrimental, but no stimulatory effect was found. Average germination of seeds from Navajo Canyon and Bernalillo planted similarly but with different soaking treatments was:

	Navajo Canyon	Bernalillo	Average
	(Percent germination)		
Seed treatment:			
None	30.0	45.3	37.6
Water, 4 hours	22.0	32.0	27.0
Thiourea			
3 minutes	16.0	37.3	26.6
6 minutes	16.7	43.3	30.0
Water, 4 hours, plus thiourea			
3 minutes	22.7	26.0	24.4
6 minutes	8.7	24.0	16.4

Hydrogen peroxide.—Although it has been shown to hasten and increase the germination of certain tree seeds, hydrogen peroxide reduced the germination of fourwing saltbush. In a test with four sources of seed, soaking for 48 hours in 6 percent peroxide gave these results:

	Peroxide	No peroxide
	(Percent germination)	
Germination temperature:		
49°	8	16
55°	7	33

In another test, seeds soaked a half-hour in 30 percent peroxide germinated only 7 percent compared with 54 percent for untreated seeds (Riffle and Springfield 1968). Further studies with a low-germi-

nating seed source showed that as little as 10 minutes of soaking in peroxide (30 percent) was detrimental.

Citric acid.—As with peroxide, citric acid has been reported to improve the germination of certain tree seeds. The citric acid was neither helpful nor harmful in concentrations of 0.02, 0.05, 0.10, 0.5, 1.0, and 2.0 percent tested on three sources of seed.

Sulfuric acid.—Although other investigators have claimed sulfuric acid improves the germination of fourwing saltbush, our results with this chemical are inconclusive. Boyd (1956) reported seeds treated in concentrated sulfuric acid for 60 minutes germinated 15 percent compared with 10 percent for untreated seeds. According to Gerard (1965), treatment in sulfuric acid for 40 minutes increased germination.

In our studies, two sources of seed treated with concentrated sulfuric acid germinated no better than untreated seeds. Because of its thick, hard seedcoat, the Madrid source in particular was expected to show improved germination when treated with acid. But, as the results below indicate, percentage germination of seeds from two sources was about the same regardless of treatment:

	Deming	Madrid
	(Percent germination)	
Untreated	61	41
Sulfuric acid:		
20 minutes	60	45
40 minutes	57	56
60 minutes	42	38
80 minutes	63	54

The lower germination for seeds treated 60 minutes is puzzling. None of the differences in germination, however, are significant statistically.

Acid-treated seeds imbibed water more rapidly than untreated seed. After 5 hours in a moist medium, acid-treated seeds had increased in weight 79 percent compared with 59 percent for untreated seeds.

Stratification

Results from several stratification studies were not consistent. We stratified seeds by putting them in moist vermiculite at 38° to 42° for 30 days.

In one study with three sources of seed, stratification apparently was harmful:

	Seeds stratified	Seeds not stratified
	(Percent germination)	
Seed source and year collected:		
Flagstaff (1961)	14	18
Datil (1962)	4	23
San Juan (1963)	17	27

In another study, however, stratification appeared to improve the germination of two of four sources of seed (table 13).

Soaking Seeds to Remove Inhibitors

Inhibitors in the seedcoat and bracts have been suspected of being responsible for the generally low germination of fourwing saltbush. Germination of other species of *Atriplex* in Australia was found to be inhibited by substances diffusing from the fruit bracts, and the inhibitor was classed as a chloride (Beadle 1952). Studies with an annual

Table 13.--Effects of different periods of stratification on the percent germination of four sources of fourwing saltbush seeds

Seed source	Germination in 30 days at 86° (8 hours); 68° (16 hours)			
	Not stratified	Stratified 10 days	Stratified 20 days	Stratified 30 days
	- - - - Percent - - - -			
San Juan	53	47	60	55
Isleta	40	32	43	46
Continental	8	10	27	30
Deming	37	37	47	51
Average	34.5	31.5	44.2	45.5

Atriplex in Israel (Koller 1957) indicated the presence of a water-soluble inhibitor that in nature is leached from the fruit bracts by rain water. Other studies in California showed enough saponin in the bracts of fourwing saltbush to reduce germination (Nord and Van Atta 1960). Twitchell (1955) found that soaking saltbush seed in water for several hours removed more that 90 percent of the chloride present and increased germination. Drying the seed for 7 days before planting gave higher germination than planting the wet seed. Similar studies by Nord and Whitacre (1957) showed that 4 hours of soaking followed by 8 days of drying did not affect germination in the laboratory.

In our studies we seldom have found any advantage to soaking the seeds in water. For example, two sources of seed were soaked 8 hours, then dried for 52 days. Germination of these seeds at two temperatures was as follows:

Germination temperature and seed treatment:	Isleta (Percent germination)	Mountainair (Percent germination)
73.3°		
Soaked	24	43
Not soaked	52	38
54.5°		
Soaked	66	58
Not soaked	70	60

The Isleta seed tended to germinate better when not soaked, and the Mountainair seed germinated about the same regardless of treatment. Another study with 2-year-old seed from Rowe, New Mexico, gave similar results.

Continuous washing in water for 2 or 4 hours did not improve germination. Two-year-old seeds from Deming, New Mexico, germinated essentially the same whether they were soaked or washed table 14). Germination was not improved by drying seeds 7 days after soaking or washing. Winged and de-winged seed responded similarly to the different treatments, except that de-winged seeds soaked 4 hours, then dried 7 days, germinated less than seeds treated other ways, for some unexplained reason.

Results of one study indicated soaking in water for 12 hours was detrimental. Percent germination in 30 days at 78° was as follows:

Seed treatment:	San Juan (Percent germination)	Isleta (Percent germination)
Not soaked	52	62
Dry chill (12 hours, 41°)	56	66
Warm soak (12 hours, 69°)	6	0
Cold soak (12 hours, 41°)	10	0

Soaking seeds in hot water definitely was harmful. Seeds were placed in boiling water and allowed to cool to room temperature—total soaking time 9 hours. Eight sources of seed treated in this manner germinated significantly less than unsoaked seeds.

Determining Seed Viability with Tetrazolium

A rapid test, with tetrazolium chloride (TZ) has been found useful for estimating seed viability of several species (Colbry et al., 1961). In the presence of TZ, living tissues stain red whereas nonliving or weak tissues do not. The principal advantage of the test is that results are available in hours rather than in weeks. Another advantage is that dormant seeds will stain red if they are viable. Thus the test gives an estimate of potential germination, which is especially valuable when seeds exhibit varying degrees of dormancy. Boyd (1956)

Table 14.--Effect on percent germination of seeds soaked or washed in water

Seed treatment and length of time treated	Germination in 30 days at 57°			
	Winged seeds		De-winged seeds	
	Dried 7 days	Not dried	Dried 7 days	Not dried
	- - - Percent - - -			
Soaked in water:				
2 hours	43	47	44	23
4 hours	36	29	15	39
Washed in water:				
2 hours	27	43	44	43
4 hours	39	35	33	35
Not treated	45	--	45	--

reported the embryos of fourwing saltbush can be stained with TZ.

Several concentrations of TZ were tried on eight sources of seed at different temperatures. The most satisfactory concentration was 0.2 percent. Degree of staining was scored from 0 to 4. Color intensity as well as pattern of staining were considered in assigning the ratings (fig. 14).

Staining of the embryos varied with source of seed. Of the eight sources tested, only seeds from Isleta consistently exceeded 50 percent well-stained embryos (ratings 3 and 4). Seeds from Monica had fewer than 20 percent well stained. A moderately high percentage of the seeds from all sources contained embryos with stain ratings of 2. This rating was assigned to embryos with incomplete staining of the cotyledons or other irregularities in stain patterns. All embryos rated 2 showed brightly stained radicles.

We attempted to correlate TZ stain ratings with germination results. The highest correlation ($r = 0.913$) was between germination percentages and the sum of ratings 2, 3, and 4 (fig. 15). Apparently, the embryo must be rather completely stained to be classed as viable, but minor irregularities in stain patterns such as included in rating 2 probably do not indicate a nonviable embryo. Instead, such embryos may be somewhat less vigorous or slightly deformed, but probably produce seedlings with a reasonable chance for survival. Embryos with 0 or 1 stain ratings, however, would not be expected to develop into normal seedlings.

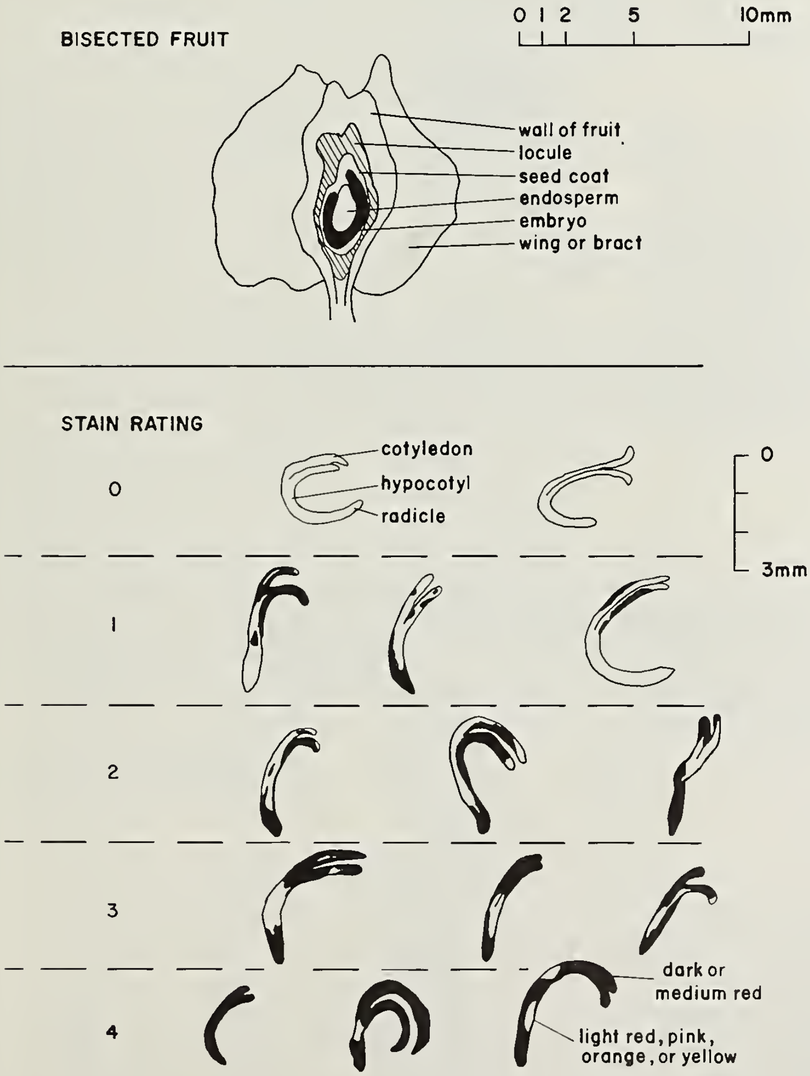


Figure 14.--Tetrazolium strain patterns and ratings.

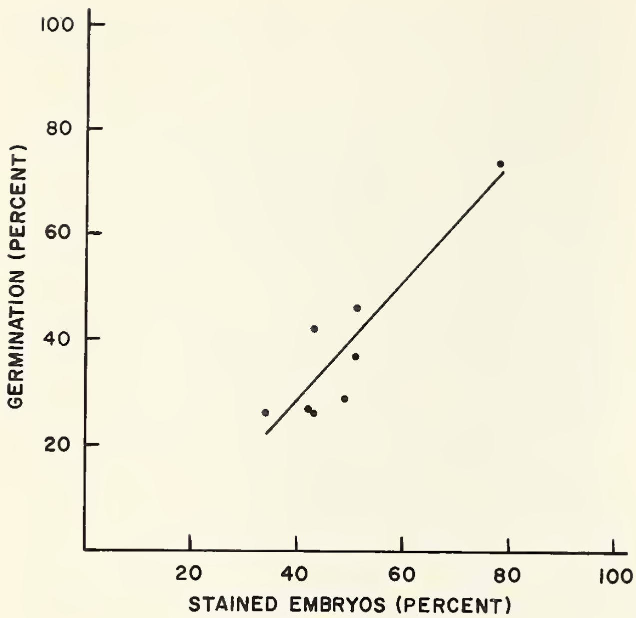


Figure 15.--Relationship between TZ ratings (percentage of seeds with embryos stained 2, 3, and 4 by tetrazolium) and average germination in 36 days at temperatures of 77°, 58°, and 42°. (r = 0.913)

The comparison between seed viability as determined by TZ stain, and actual germination was closer for some sources of seed than others (fig. 16). Closest in agreement were the Isleta, Mountainair, and Flagstaff seed; the two methods agreed within 5 percent or less. Three of the remaining five sources agreed within 8 to 15 percent. Poorest agreement was for the Beaver Creek and Chevelon sources. Seed dormancy is suspected where germination was substantially less than the viability indicated by TZ staining.

Seedling Characteristics

A variety of studies were conducted to determine seedling emergence, mortality, and growth in different soils. These studies were made outdoors with no control over temperature. Moisture was held near field capacity for most studies.

Emergence and Mortality

Seedlings begin emerging within 6 to 10 days, provided moisture is adequate and temperatures are not extreme. Germination is epigeous. Usually the first visible sign of emergence is an arched hypocotyl (fig. 17). The seed ordinarily remains in the soil, but sometimes it is lifted above the surface and remains attached to the cotyledons several days; this happens more often with dewinged seed and in shallow seedings. Emergence usually is complete within 12 to 20 days.

Seedling emergence and growth are largely dependent on temperature and moisture. In studies with 1-year-old seeds from Delta, Colorado, planted in a sandy loam soil March 18, most of the seedlings emerged during a period when air temperatures ranged from 68° - 75° during the day and 37° - 42° at night (table 15). Height growth was greatest when day temperatures were about 80° and night temperatures about 46°.

Seedling emergence varies widely with source of seed. This undoubtedly reflects differences in seed fill, and possibly physiological makeup among seed sources. In one study, eight sources of seed were germinated in soil obtained from beneath a mature saltbush. Seeds were planted in flats August 26; final seedling counts were taken October 7. Soil was kept moist by daily sprinkling in August and at 2- to 5-day intervals thereafter. Daytime temperatures during the first 2 weeks ranged from 78° to 92°; night temperatures from 54° to 70°. Emergence and mortality of seedlings varied widely:

Seed source	Emergence (Percent)	Mortality (Percent)
Arizona:		
Flagstaff	24	12
Tuba City	27	0
New Mexico:		
Corona	27	12
Glenwood	57	0
Hatch	12	0
Lovington	45	33
Magdalena	21	29
Monica	30	20

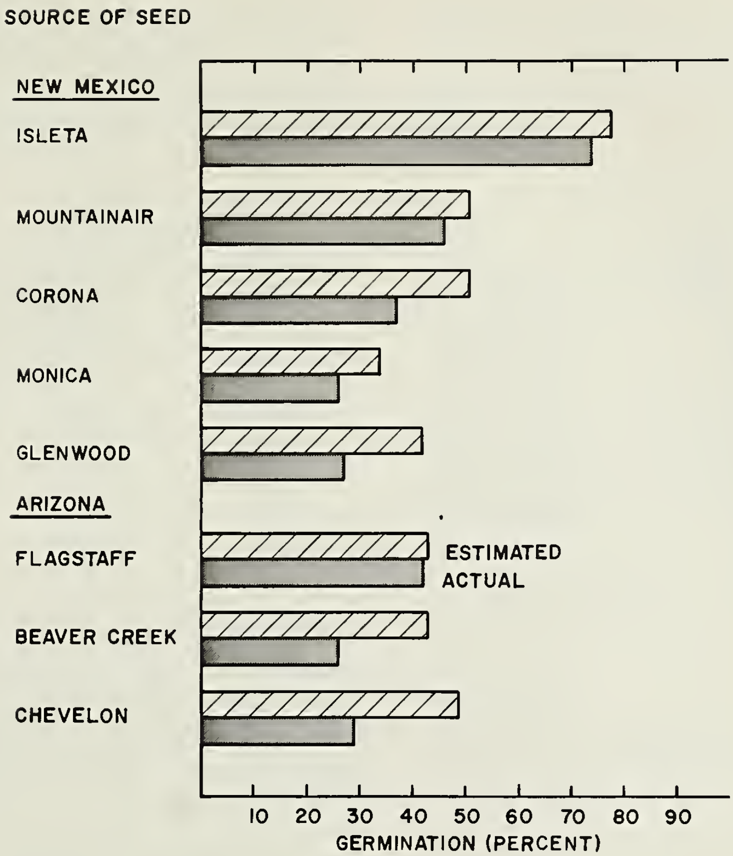


Figure 16.--Comparison between estimated potential germination percentages (TZ-stained embryos, rated 2, 3 and 4) and average actual germination percentages (at 77°, 58°, and 42°) for eight sources of fourwing saltbush seed.

Table 15.--Seedling emergence and height growth from 1-year-old seeds planted in sandy loam soil, March 18 (Seed source: Delta, Colorado)

Date measured	Seedling development		Weather conditions between dates		
	Emergence	Height growth	Precipitation	Maximum temperature	Minimum temperature
	Percent	Inches	Inches	- - - - °F.	- - - -
April 7	24	0.5	0.58	68	37
14	36	.8	.24	75	42
21	40	1.1	.45	82	48
29	40	1.4	.38	72	42
May 12	40	4.0	.82	80	46
30	45	6.1	1.33	81	47

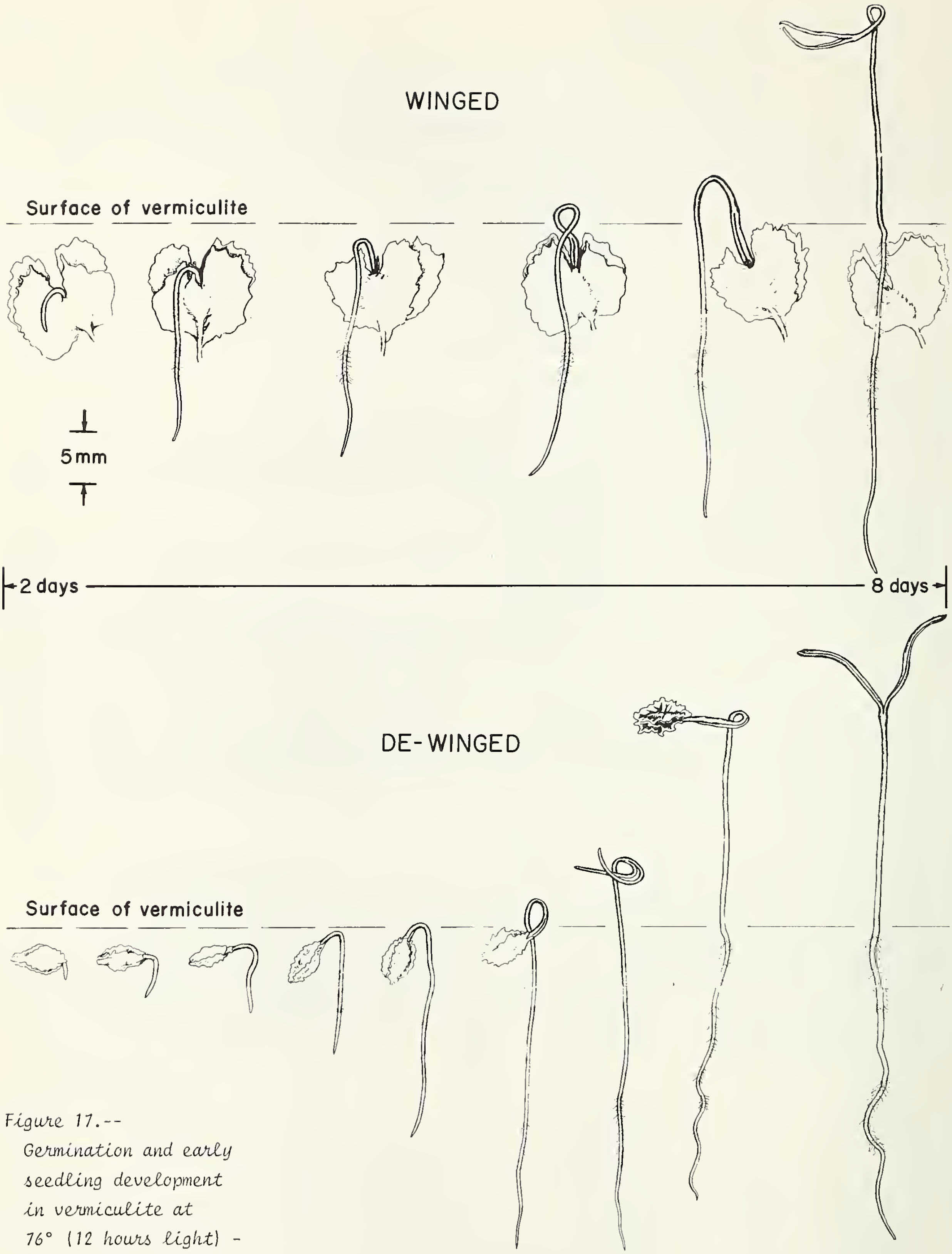


*Figure 17.--
Germination and early seedling development in vermiculite at 76° (12 hours light) - 60° (12 hours dark).*

Studies conducted in a representative pinyon-juniper soil obtained near Santa Fe produced similar results. Seeds were planted September 12, seedlings began emerging September 20, and final counts October 14 showed the following:

Seed source	Emergence	Mortality
	(Percent)	
Arizona:		
Benson	27	0
Willcox	15	26
New Mexico:		
Corona	69	0
Glenwood	62	0
Hatch	48	8
San Felipe	7	0
Utah:		
Ephraim	33	19

Seedling mortality was less in sandy loam soil than in other substrata in another nursery study. Two-year-old seed from Chevelon, Arizona, were planted in nursery trays filled with different substrata. Day temperatures ranged from 75° to 88° and night temperatures from 43° to 62°. Results were as follows:

Substrate	Emergence	Mortality
	(Percent)	
Sandy loam	28	0
Perlite	40	20
Vermiculite	24	33

Since the perlite and vermiculite are relatively inert and not apt to contain disease organisms, mortality presumably was caused by seedborne organisms. Poorer aeration in the perlite and vermiculite than in the sandy loam soil could have been a contributing factor.

Treatments to Control Disease Organisms

Mortality of fourwing saltbush seedlings sometimes is extremely high. Examination of seeds and seedlings has revealed contamination by *Alternaria* and *Fusarium* (Riffle and Springfield 1968). In one nursery study with 2-year-old seed from Mountainair, conducted under low light intensity when daytime temperatures ranged from 78° to 94°, mortality varied from 88 to 100 percent. In a hand-seeding trial at the Corona site, seedling establishment was higher from fungicide-treated seeds than from untreated seeds. The number of seedlings per foot of row with seeds from Isleta and Corona was:

	Isleta	Corona
	(Number)	
Dusted with Arasan	2.5	1.0
Not treated	.5	.5

Fungicidal treatment of seeds has not always reduced seedling mortality. In a nursery study with 1-year-old Lordsburg seed, when daytime temperatures were 48° to 62° and night temperatures 25° to 36°, results were as follows:

Seed treatment	Emergence	Mortality
	(Percent)	
None	16.3	0
Soaked 8 hours	20.7	19
Not soaked - fungicide	45.7	0
Soaked 8 hours - fungicide	37.3	23

Although mortality was not affected, fungicidal treatment (Captan) significantly increased emergence. Perhaps the fungicide was effective in controlling seedborne organisms that were detrimental to seedling emergence. These results are in disagreement with those reported by Hervey (1955), who found fungicidal treatment of seeds did not affect germination.

Control of soil pathogens through fumigation improved seedling establishment in two of three soils studied. Highest seedling establishment resulted from fumigation of Wingate soil. The number of established seedlings per 100 seeds planted in three soil types was:

	Soil type		
	Wingate	Silver Hill	QRA
	- - - (Number) - - -		
Soil and seed treatments:			
Soil fumigated			
Fungicide	37	3	10
No fungicide	20	7	23
Soil not fumigated			
Fungicide	13	7	3
No fungicide	10	0	0

Seeds were planted 0.5 inch deep. Soil moisture was kept near field capacity for 2 months. Seedlings emerged and became established more readily in the Wingate clay soil than in the Silver Hill loamy sand or QRA heavy sandy loam. These figures suggest harmful micro-organisms could be present in the Wingate and QRA soils. Dusting seeds with fungicide (Arasan 75) was beneficial only for seedlings in the Wingate soil.

Growth in Different Soils

Fourwing saltbush seedlings generally grow better in soils from representative sites than in horticultural mixes. For these growth studies, 2- to 4-week-old seedlings were transplanted to gallon containers filled with different soils or mixes. Heights of 10-month-old seedlings grown from the Isleta seed source, for example, were as follows:

	Average height (Inches)
Soil collected from under:	
Mature saltbush	12.8
Pinyon	11.8
Cercocarpus	10.2
Blue grama	8.2
Winterfat	8.0
Horticultural mix (2 parts sand, 1 part peat, 1 part loam)	3.9

Studies with five other sources of saltbush showed 1-year-old plants generally grew taller in soil from the Santa Fe area (table 16). Four of the sources grew best in a soil taken from beneath shrubs (cercocarpus) near Santa Fe (fig. 18). Poorest growth was in a grassland soil from the Rio Puerco. Height growth also was relatively poor in Corona soils, both those from beneath grass and juniper trees. Growth was poorer than expected in soil collected near Magdalena beneath mature saltbush plants.

Methods of Establishment

Methods of establishment have been studied at several sites representative of the pinyon-juniper type (see table 1). These sites range in elevation from 6,300 to 7,500 feet. Soils vary from loamy sand to clay. Though most were hand trials, some of the methods involved mechanized equipment. The most comprehensive tests were conducted at the Monica site, where different kinds of tractor-drawn equipment were compared for site preparation and seeding.

Direct Seeding

Small-Scale Field Trials

Investigations included comparisons among various depths of furrows, mulching, and soil-firming treatments.

Seedling establishment was about the same in shallow furrows (1 to 2 inches deep) as in deep furrows (3 to 4 inches deep) at the Silver Hill site. The number of seedlings per foot of row (10 seeds) that became established from a July seeding was:

	Shallow (Number)	Deep (Number)
Seed source:		
Corona	0.5	0.6
Deming	.1	.2
Isleta	.1	.0
Gran Quivira	.4	.2

Some sloughing of the sandy soil from the sides of the furrows may have covered seeds too deeply, especially in the deep furrows. Natural sloughing of the soil resulted in complete failure from a June seeding in deep furrows at the Monica site.

Removal of competing vegetation would seem to be necessary for satisfactory seedling establishment. Three methods of seedbed preparation were compared at the Monica site: (1) all competing vegetation removed by rototilling, (2) grasses killed by spraying with dalapon 1 month before seeding, and (3) untreated blue grama sod. Furrows 1 to 2 inches deep were made by hand in each seedbed. Ten seeds per foot of row were distributed, and covered with about 0.5 inch of soil. The number of seedlings per foot of row from seedings made July 1965 with 2-year-old seeds from Lamy, New Mexico, by seedbed preparation, was:

Seedbed	1965 August	1965 November	1966 October	1967 October
Rototilled	2.1	1.2	0.9	0.9
Sprayed	1.8	1.3	.9	.8
Unprepared	1.4	.2	.1	.1

Table 16.--Average heights of 1-year-old fourwing saltbush plants grown in soils taken from beneath grass, shrubs, or juniper trees at four sites in New Mexico

Soil site and location sampled	Plant height					
	Source of seed					Average
	Canjilon, New Mexico	Lamy, New Mexico	Rowe, New Mexico	Keams, Arizona	Delta, Colorado	
	Inches					
Santa Fe:						
Beneath grass	17.1	15.3	14.4	10.0	14.3	14.2
Beneath shrubs	16.5	17.3	16.4	14.2	15.9	16.1
Corona:						
Beneath grass	6.4	9.9	15.0	7.7	7.0	9.2
Beneath junipers	8.9	8.1	10.3	13.1	7.9	9.7
Rio Puerco:						
Beneath grass	5.8	8.2	7.1	5.6	([1])	6.7
Magdalena:						
Beneath shrubs	10.2	12.7	14.1	9.0	8.8	11.0

[1]Plants died.

Figure 18.--Plants grown from three sources of seed in different soils (CERC = soil from beneath cercocarpus, Santa Fe; COR = soil from Corona; MAG = soil from Magdalena; RP = soil from Rio Puerco; G = grassland soil; W = woodland soil).

Initial seedling establishment was high for all three kinds of seedbeds, but most seedlings died on the unprepared seedbed, apparently as a result of competition for moisture from blue grama roots. By contrast, seedling survival was good where blue grama competition was removed either chemically or mechanically. Survival in these shallow furrows was nearly as high as in pits and basins (number of seedlings per foot of row):

	1965 August	1966 October	1967 October
Handmade pits (4 inches deep)	2.6	1.2	1.0
Handmade basins (6 inches deep)	3.4	1.0	.9

The pits and basins of Monica were made and seeded at the same time as the furrows. Moreover, the same seed source and seeding rates were used, so the results are comparable. Although seedling establishment was appreciably higher in pits and basins 1 month after seeding, survival 2 years later was only slightly greater than in shallow furrows.

Similar results were obtained at the QRA site. Seedings were made in July 1966 in furrows 1 to 2 inches deep on sites prepared three ways. Counts (number of seedlings per foot of row) in 1966 and 1967 showed the following:

	1966 October	1967 March	1967 August
Vegetation scalped	0.42	0.19	0.08
U-shaped basin (5 inches deep)	1.58	.86	.47
Enclosed basin (5 inches deep)	.94	.75	.42

Runoff water flowed into the U-shaped basin, whereas only rain water accumulated in the enclosed basin. Higher establishment in the basins is attributed to extra moisture collected and held.

Depth to Seed

Experience indicates that planting the seeds too deeply could be responsible for a number of seeding failures. Seedings failed in 2 consecutive years at a site with coarse-textured soil in central New Mexico. Few seedlings emerged despite favorable precipitation. In both years, de-winged seeds were sown in furrows 3 to 5 inches deep. Seeds were covered with only 1 inch of soil in the seeding operation, but the seeds became covered with 2 to 3 inches of soil that sloughed off the sides of the furrows.

In depth-of-seeding studies, seeds were planted at depths of 0.5, 1, 1.5, and 2 inches in sandy loam and clay loam soils (fig. 19). Moisture was held

Figure 19.--Depth-of-seeding test.

Rows of different depths were planted with 100 seeds.

Seedling emergence in sandy loam soil at the end of 30 days.

near field capacity throughout the study. Seedling emergence was significantly greater from 0.5 inch than from 1.5 or 2 inches (table 17). Seedlings also emerged more rapidly from the shallow seeding (fig. 20). Essentially the same number of seedlings emerged from the sandy loam and clay loam soils, though the trend was toward more seedlings from the greater depths in the clay loam soil.

The results indicate de-winged seeds should not be planted more than 1 inch deep. Regardless of method of seeding, precautions should be taken where there is danger of soil sloughing from the sides of furrows, or of additional soil being washed or blown in over the seeds.

Although seedling emergence was practically the same in the sandy loam as in the clay loam soil, soil texture could be a consideration in depth of seeding. Optimum depth probably would be greater in a sandy soil than in a clay soil under range conditions, where available moisture fluctuates from day to day.

Seeding depths of 0.5 to 1 inch are suggested for de-winged seeds. Cassady (1937a) reported greatest seedling emergence from seeding depths of 0 and 0.5 inch for winged seeds. Wilson (1928) recommended 0.25- to 1.5-inch seeding depths for winged seeds.

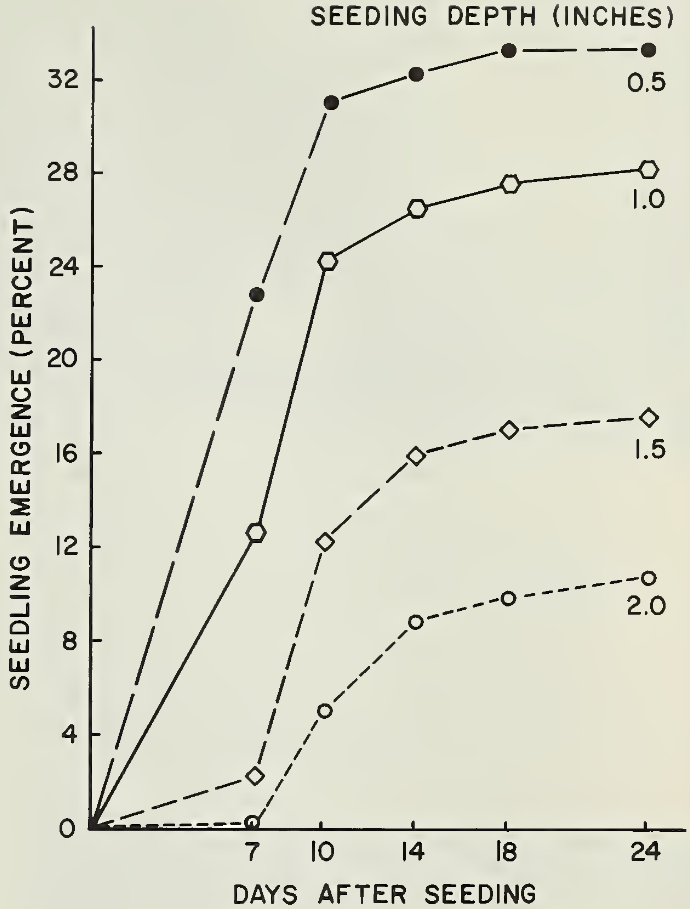


Figure 20.--Rate of seedling emergence from four depths of seeding.

Table 17.--Average percent emergence of four-wing saltbush seedlings from four depths of seeding

Soil type and treatment	Seedling emergence by planting depth			
	0.5 inch	1 inch	1.5 inches	2 inches
	- - - Percent - - -			
Sandy loam				
Packed	34.7	27.5	10.0	4.0
Not packed	38.3	29.7	16.7	16.7
Clay loam				
Packed	25.7	31.3	25.7	13.7
Not packed	36.0	26.7	19.0	9.3
Average[1]	33.7a	28.4ab	17.8bc	10.9c

[1]Values followed by the same letter do not differ significantly at the 0.05 level.

Mulches

Mulching usually has improved seedling establishment. At the Corona site, for example, seedling establishment 3 months after seeding averaged higher where a light layer of grass mulch was placed over the seeded rows (table 18). Survival 2 and 4 years later also was higher in the mulched rows. Results of the various packing treatments compared in this study, however, were inconclusive. In a similar study, also made at the Corona site in August 1965, when the soil was moist, mulching appeared particularly beneficial where soil was

packed over the seeds. The number of seedlings per foot of row was:

	November 1965	November 1966	November 1967
	- - (Number) - -		
Packed			
Mulched	1.7	0.9	0.8
Not mulched	1.5	.6	.4
Not packed			
Mulched	.6	.2	.2
Not mulched	.6	.2	.2

Packing probably resulted in better contact between moist soil and the seeds, and the layer of grass mulch protected the soil from drying. According to Cassady (1937b), emerging fourwing saltbush seedlings seem to require plant litter for protection. He suggested either allowing litter to accumulate naturally, or cutting shrubs and scattering them over seedings.

Rather comprehensive mulching studies were conducted at the Santa Fe Lab and the QRA site in 1967 and 1968. The objective of these studies was to test the concept of seeding in moist soil, then applying a mulch to delay moisture losses so as to improve seedling establishment. In both years, the Santa Fe Lab studies were started in July and the QRA studies in August. Seeds were planted in furrows 2 to 3 inches deep and 10 feet long. Seeding rate was 15 viable seeds per foot of row. Seeds were covered with 0.5 inch of soil. Mulches were applied immediately after seeding (fig. 21). Included as mulches were oat straw, aluminized asphalt,[7] white petroleum resin,[7] and Soil Gard.[8] Soil moisture was determined at 1- to 3-day intervals by gravimetric sampling. Soil temperatures were measured by thermistors placed in the test rows at the same level as the seeds and covered with the same amount of soil and mulch material.

In the 1967 study at Santa Fe, seeds were planted and mulches applied July 10, 1967. Seedlings began emerging July 18, emerged rapidly from July 21 to 24, and reached maximum stands

[7] *Experimental products supplied by Dr. R. L. Fern, Chevron Research, Richmond, California. Aluminized asphalt identified as 64R-1101; white petroleum resin, 68R-5268.*

[8] *A latex compound manufactured by Alco Chemical Corp., Philadelphia, Pa.*

Table 18.--Survival of fourwing saltbush seedlings at the Corona site in November 1964, 1966, and 1968; seeds from two sources were planted in July 1964

Seedbed treatment	Seedling survival by seed source: Taos seed 1964	Taos seed 1966	Taos seed 1968	Lamy seed 1964	Lamy seed 1966	Lamy seed 1968
	- - - Number per foot of row - - -					
Packed before seeding:						
No mulch	0.3	0.3	0.3	0.7	1.0	1.0
Mulch	1.3	.7	.7	3.7	1.7	1.3
Packed after seeding:						
No mulch	1.3	0	0	1.0	1.0	1.0
Mulch	1.3	.7	.7	1.0	1.3	1.0
Packed before and after seeding:						
No mulch	.3	0	0	1.0	.7	.3
Mulch	.7	.7	.7	1.3	1.0	.7
Average						
No mulch	.6	.1	.1	.9	.9	.8
Mulch	1.1	.7	.7	2.0	1.3	1.0

Figure 21.--1968 Santa Fe Mulch Study. Immediately after seeds were planted in 10-foot-long rows, mulches were applied.

Soil temperatures were measured with thermistors. Row at right is mulched with white petroleum resin.

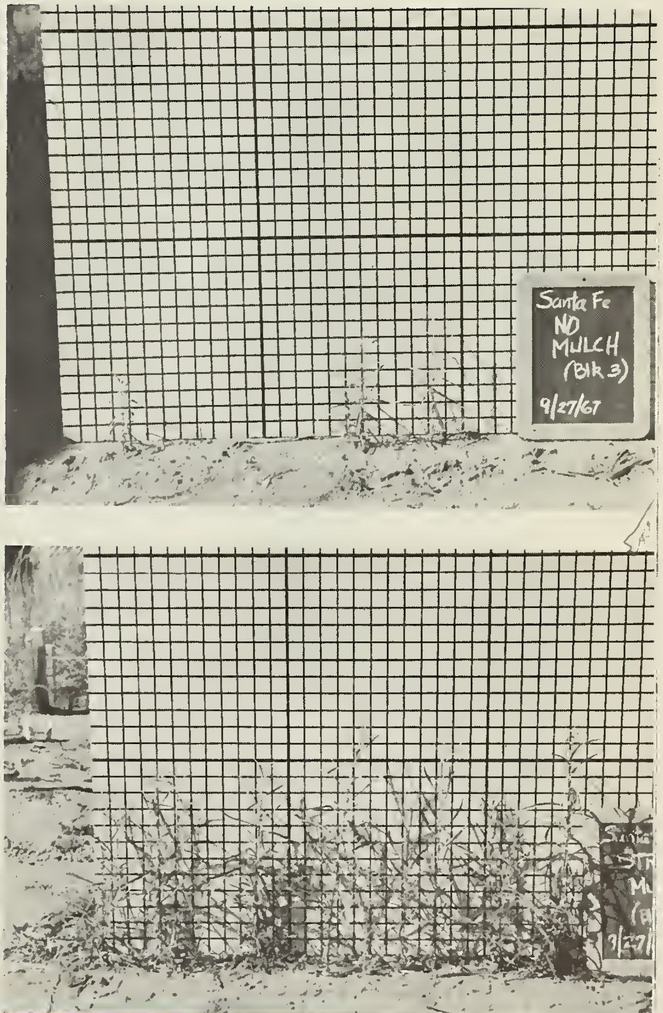
August 28. The number of seedlings per foot of row under straw and asphalt mulches was:

	Mulch treatment		
	Straw	Aluminized asphalt	None (control)
	(Number of seedlings)		
Seedlings counted:			
July 18	0.8	0.1	0.1
July 21	1.4	.8	.3
July 24	2.5	1.0	.4
July 28	2.7	1.0	.5
August 7	3.4	1.0	.5
August 14	3.5	1.1	.6
August 18	3.5	2.3	.7
August 28	3.6	2.7	.7
September 5	3.4	2.6	.7

Seedling establishment was best in rows mulched with straw (fig. 22), and rows mulched with aluminized asphalt produced stands substantially better than unmulched rows. Moisture in the top inch of soil fluctuated with rainfall (fig. 23). Unmulched soil generally was drier than mulched soil the first 2 weeks, when seedlings were emerging. None of the mulches was completely effective in preventing losses of soil moisture, but mulched soil was more moist than unmulched soil 3 to 4 days after seeding, and again 8 to 11 days after seeding. Soil temperatures were lower under the straw than under the other mulches (table 19), which helps explain the better seedling emergence in rows mulched with straw.

In the 1967 QRA mulch study, seeds were planted and mulches applied August 10. Seedling emergence was good (more than one plant per foot of row) for all treatments, largely because of 2 weeks of cool, wet weather after the date of seeding. Soil moisture was adequate for good seedling emergence even in the unmulched rows.

Figure 22.--Seedlings established in 1967 Santa Fe Mulch Study. Best establishment was in rows mulched with straw.



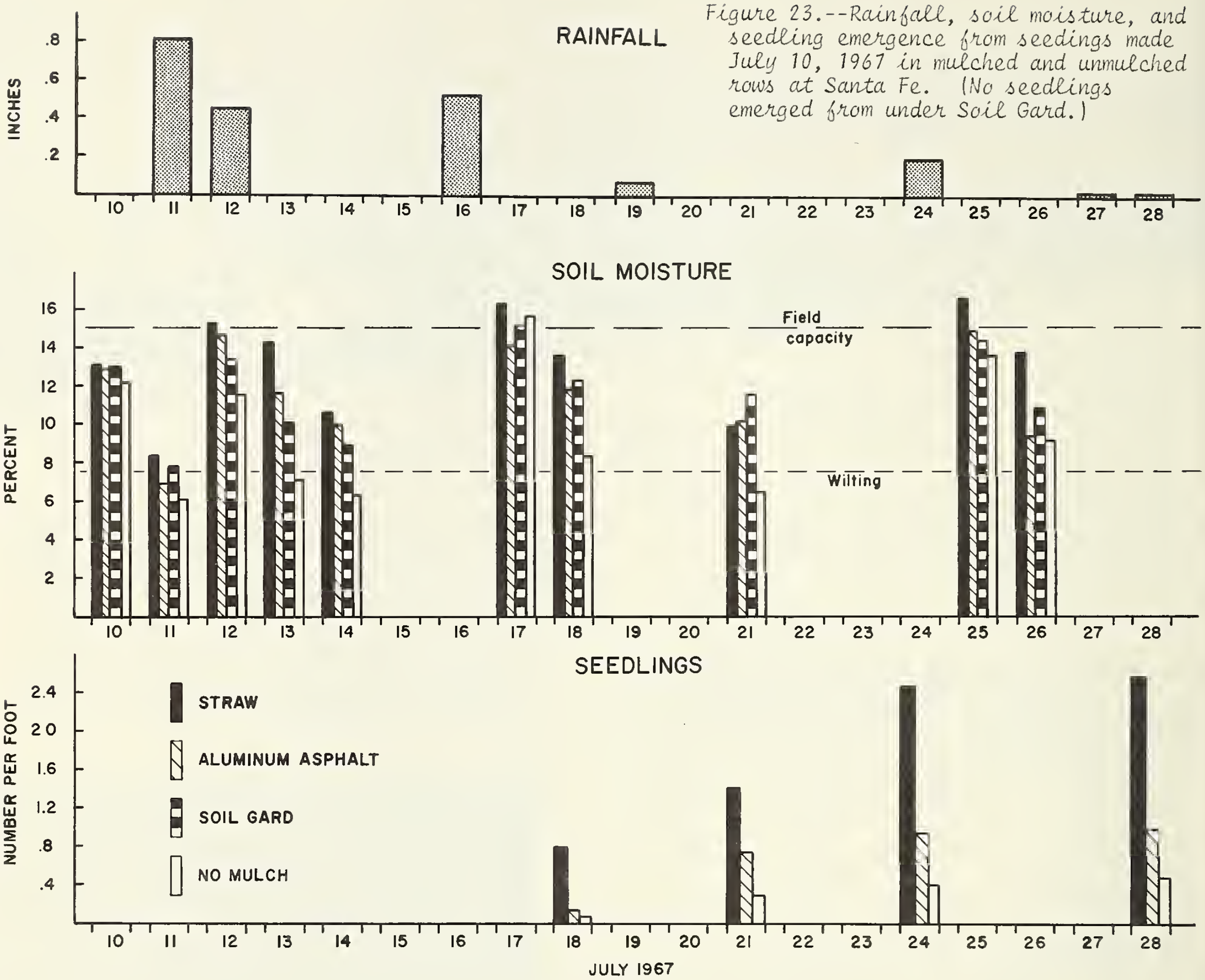


Figure 23.--Rainfall, soil moisture, and seedling emergence from seedings made July 10, 1967 in mulched and unmulched rows at Santa Fe. (No seedlings emerged from under Soil Gard.)

Table 19.--Representative soil temperatures under different mulches at the 0.5-inch depth during the first 2 weeks following seeding and mulching at the Santa Fe Lab site on July 10, 1967

Air temperature in shade (°F.)	Soil temperature (°F.) under each mulch			
	No mulch (Control)	Straw	Aluminized asphalt	Soil Gard
54	57	64	62	59
60	60	63	62	62
66	68	68	71	67
70	87	72	86	95
79	92	79	95	105
86	104	83	100	111
90	112	87	107	113
92	119	87	109	114

Effective rains fell August 11, 15, and 21. More than twice as many seedlings emerged in rows mulched with Soil Gard as in unmulched rows (table 20). The better seedling emergence is attributed to slightly higher soil moisture under Soil Gard.

The 1968 Santa Fe Lab mulch study was begun July 9. Because rainfall was negligible during the first 9 days, the various mulches were well tested. Losses in soil moisture were less under the mulches than in the unmulched rows (fig. 24). Seedlings began emerging the 6th day after seeding. Stands that emerged in rows mulched with straw or white petroleum resin were significantly better than those in other rows. Temperatures during the first week were much cooler, particularly from 10 a.m. to 6 p.m., under the straw and white petroleum resin (table 21). These cooler temperatures, together with favorable soil moisture, help explain why seed-

Table 20.--Emergence and survival of fourwing saltbush seedlings, in relation to mulch treatments at QRA site, August 10, 1967

Date of observation	Seedling survival by mulch treatment			
	No mulch (Control)	Native grass[1]	Aluminized asphalt	Soil Gard[2]
	- - - - - - - Number - - - - - - -			
1967:				
August 21	2.3	3.6	2.6	5.9
August 28	2.2	2.4	2.8	6.1
September 11	2.4	2.0	2.7	5.6
October 13	2.7	1.4	2.8	5.6
1968:				
May 9	2.4	1.1	2.8	4.9
October 28	2.4	1.1	3.0	4.4

[1]Application probably too heavy.
[2]Latex compound applied 1 part chemical to 4 parts water.

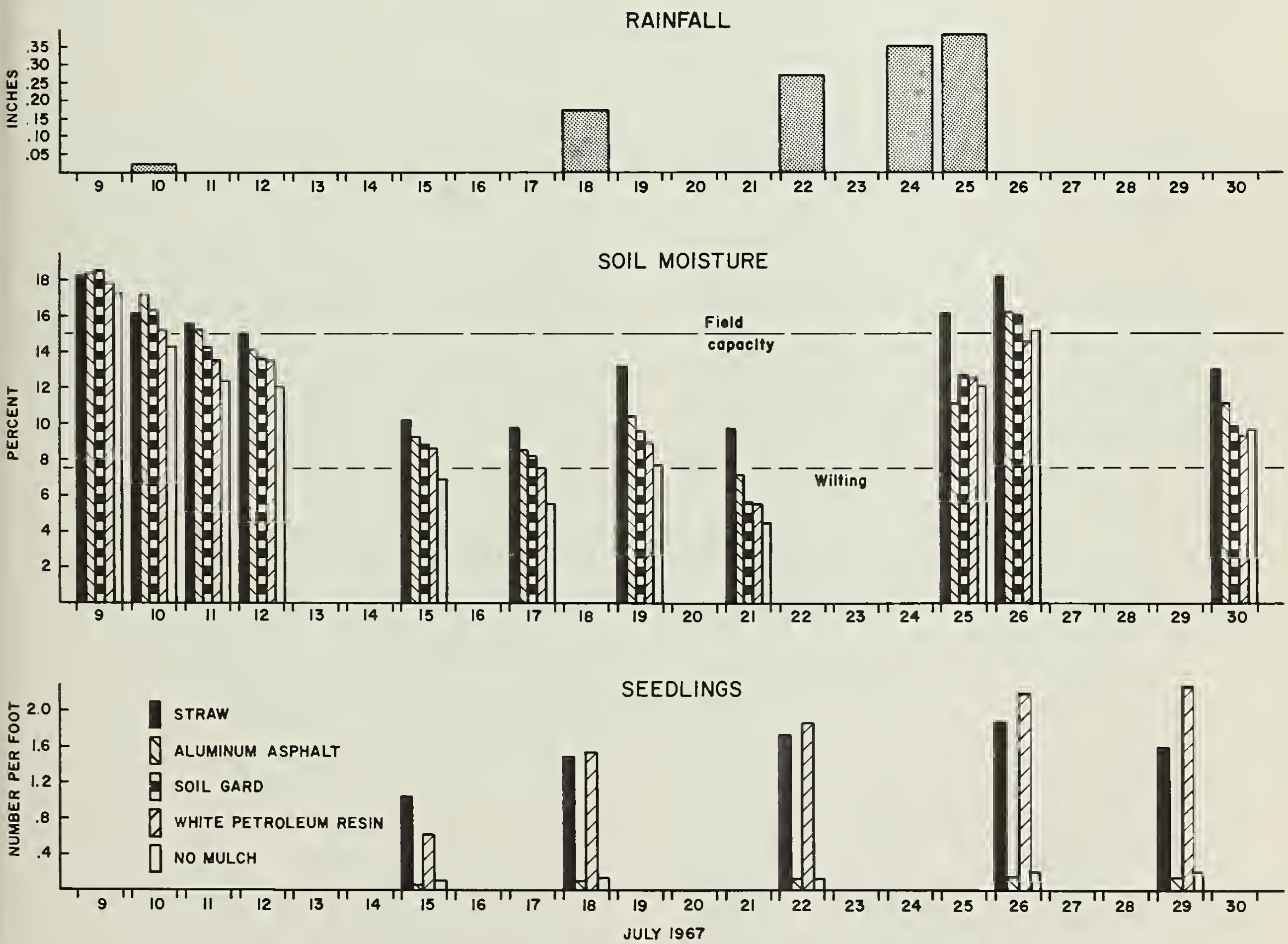


Figure 24.--Rainfall, soil moisture, and seedling emergence from seedings made July 9, 1968 in mulched and unmulched rows at Santa Fe. (No seedlings emerged from under Soil Gard.)

Table 21.--Average soil temperatures under different mulches during the first week after seeding and mulching at the Santa Fe Lab site on July 9, 1968

Time of day (2-hour periods)	Air temperature	Soil temperature by mulch treatment				
		No mulch (Control)	Straw	Aluminized asphalt	White petroleum resin	Soil Gard
	- - - -	- - - -	- - - °F.	- - - -	- - - -	- - - -
8 to 10 a.m.	66.5	65.3	64.1	67.1	60.6	66.1
10 to 12 noon	71.1	78.0	69.5	88.8	67.4	84.8
12 to 2 p.m.	79.2	91.6	77.7	92.5	74.6	97.6
2 to 4 p.m.	84.2	103.1	82.6	100.2	80.0	107.6
4 to 6 p.m.	80.8	85.7	76.7	86.3	72.1	91.2
6 to 8 p.m.	72.4	80.1	75.8	81.5	69.4	82.1
8 to 10 p.m.	64.6	73.8	72.8	76.0	65.5	75.2
10 to 12 midnight	60.2	67.7	69.0	72.5	61.6	69.6
12 to 2 a.m.	60.2	65.6	66.6	69.1	60.6	66.8
2 to 4 a.m.	60.4	63.7	65.0	67.5	59.1	65.0
4 to 6 a.m.	62.3	63.5	64.1	67.4	59.0	64.8
6 to 8 a.m.	62.7	63.3	63.9	66.6	58.8	64.6

ling emergence was higher where straw or white petroleum resin were applied. By contrast, temperatures exceeding 100° were recorded from 2 to 4 p.m. at the seed zone in unmulched rows and in rows mulched with Soil Gard or aluminized asphalt.

The 1968 QRA mulch study was installed August 14. By August 23, seedlings had emerged in rows mulched with either straw, aluminized asphalt, or white petroleum resin (table 22). This emergence resulted from moisture in the soil at the time of seeding. Effective rains fell August 20, 26, and 28. As a consequence, seedlings emerged in all test rows. Peak numbers were reached on September 12, after which stands declined. Differences in temperature, as well as soil moisture, under the various mulches account for the differences in seedling emergence. Soil temperatures the 5th day after seeding, when all mulches were intact and functioning, show a wide spread among the different mulch treatments during the afternoon hours (fig. 25). At 3 p.m., for example, the temperature

Table 22.--Emergence and survival of fourwing saltbush seedlings in relation to mulch treatments at QRA site, August 14, 1968

Date of observation, 1968	Seedling emergence and survival by mulch treatment				
	No mulch (Control)	Straw	Aluminized asphalt	White petroleum resin	Soil Gard
	- - - -	- Number	per foot of row	- - -	- -
August 23	0.17	5.78	4.69	2.08	0.03
August 27	.14	6.25	5.28	2.22	.03
September 3	4.75	7.44	5.97	5.64	3.14
September 12	5.00	7.31	6.06	5.83	3.22
October 7	3.22	6.00	5.56	4.61	1.58
October 28	3.06	5.75	5.47	4.50	1.58

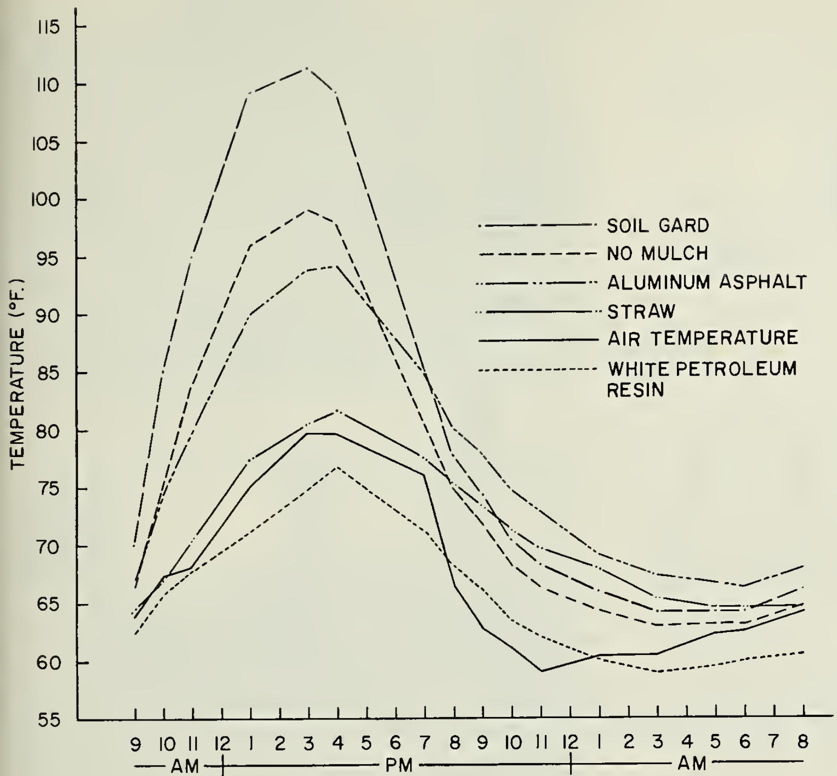


Figure 25.--Soil temperatures August 19-20 in the seed zone (0.5 inch deep) under different mulches at the QRA site. Seeds planted and mulches applied August 14, 1968.

under Soil Gard measured 111° compared with only 75° under white petroleum resin and 80° under straw. All of the mulches, except Soil Gard, lowered the soil temperature to less than that of unmulched soil from 1 to 4 p.m. During the first 5 days after seeding, soil moisture dropped sharply (fig. 26). Soil moisture exceeded field capacity in all rows at the time of seeding, yet by the 5th day, moisture was only 5 percent in unmulched rows as against 7.4 percent in rows mulched with straw. Soil moisture remained in excess of 7 percent under the aluminized asphalt from the date of seeding to September 3, which undoubtedly explains the good seedling emergence for this mulch. Moisture under straw likewise remained higher than for the other treatments throughout the first 2 weeks. None of the mulches, however, was fully effective in preventing moisture losses from the top inch of soil.

Results of these mulch studies support the concept of seeding when the soil is moist, and delaying moisture losses by applying mulch over the seeded rows. If mulches are used to improve chances of success from summer seeding, the mulch material should function to reduce afternoon soil temperatures, such as straw and white petroleum resin did in our studies. Otherwise the mulch material, like Soil Gard, may cause the top layers of soil to heat up to temperatures that inhibit germination. This characteristic of certain mulches to raise the soil temperature could be an advantage, however, for seeding during the cooler seasons. For example, the seeds might be placed in moist soil in early spring when the temperatures are low, then covered with a mulch such as Soil Gard, black asphalt, or black polyethylene. The mulch would serve the dual purposes of conserving soil moisture and raising soil temperatures.

Mechanized Trials

Seedbed preparation probably is necessary to obtain good stands of fourwing saltbush. Wilson (1928) reported failures from broadcasting the seed without seed coverage, but obtained satisfactory stands when the seeds were broadcast and then covered by disking. In 26 trials, Bridges (1941) obtained a good stand from only one. He blamed rabbits, poor seedbed preparation, and wrong time

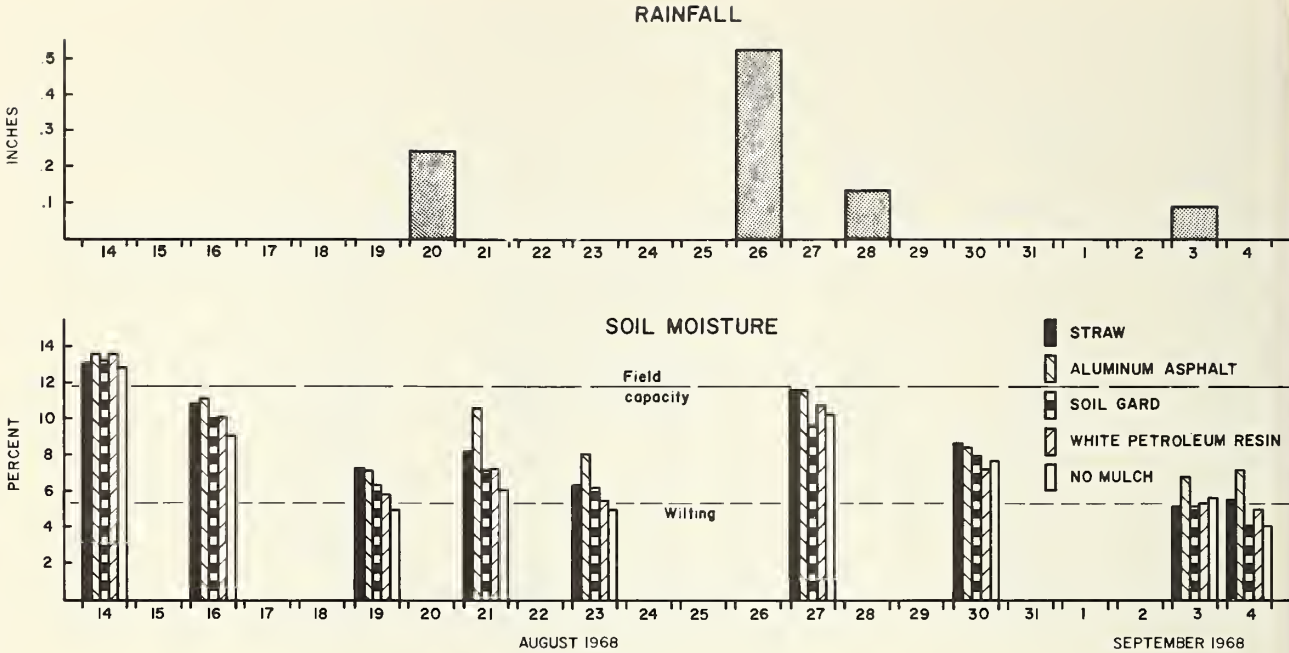


Figure 26.--Precipitation and soil moisture under mulches at the QRA site during the first 3 weeks after seeding. Seeds planted and mulches applied August 14, 1968.

of seeding for the failures. In studies at the Monica site in west-central New Mexico, plants were established by drilling into drought-weakened blue grama sod, but resulting stands were much poorer than those on prepared seedbed (Springfield 1963).

In our studies at the Monica site, methods of seeding included (1) drilling and (2) cultipacker seeding. Seedbeds were prepared by (1) plowing, (2) pitting, (3) plowing and pitting, and (4) no cultural treatment (fig. 27). Rate of seeding was 20 pounds of de-winged seed per acre, or about six viable seeds per square foot.

Emergence (number of seedlings per square foot) 2 months after seeding varied according to method of seedbed preparation and seeding:

Seedbed preparation	Grain drill	Cultipacker-seeder
	(Number of seedlings)	
None	0.22	0.12
Pitted	.55	.70
Plowed	.68	1.38
Plowed-pitted	.58	1.12

Significantly fewer seedlings emerged on the unprepared seedbed; other differences were not significant. The trend, however, was toward more seedlings wherever the cultipacker-seeder was used on loose seedbeds.

Eleven years after the plots were seeded, significantly more plants were still present on prepared than on unprepared seedbeds (fig. 28). No differences in number of plants were measured, however, among pitted, plowed, or plowed-pitted seedbed. Comparisons of the two seeding methods indicated better stands with cultipacker seeding on plowed seedbeds. Beneficial effects of cultipacker-seeding were especially noticeable on plowed-pitted seedbeds.

Less than half the seedlings present the year of seeding survived as mature plants 11 years later:

Preparation	Average survival (Percent)
Pitted	41
Plowed	30
Plowed-pitted	35

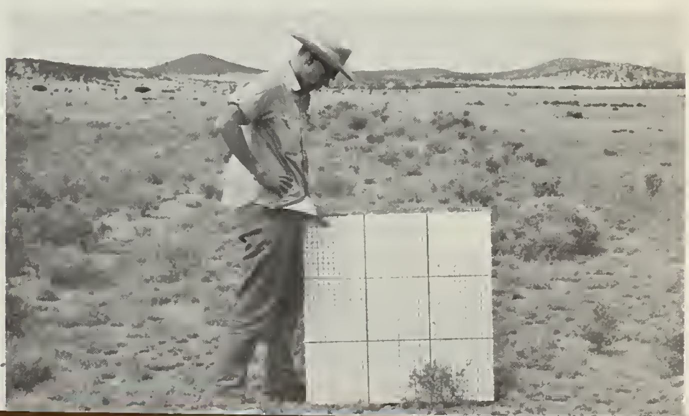
Figure 27.--Two methods of seeding were compared on four kinds of seedbeds at the Monica site where fourwing saltbush seeds were planted June 1951.

Cultipacker seeder on plowed-pitted seedbed.

Drilling on unprepared seedbed (pitted seedbed in foreground).

Figure 28.--Fourwing saltbush plants were evaluated in August 1962, 11 years after planting on the Monica site. More plants had become established on prepared than unprepared seedbeds.

Plowed.



Unprepared.

Average heights and diameters of plants in the 11-year-old stands were about the same, regardless of the method of seedbed preparation and seeding. Crown cover, however, was substantially higher on prepared seedbeds than on the unprepared seedbeds.

Of three methods of seedbed preparation tested, none proved definitely superior. Where there is a remnant of desirable species, pitting or furrowing may be preferable, but where the native cover is composed mainly of undesirable plants, plowing probably would be best.

Although seedbed preparation appears necessary for the establishment of good stands, the seeding of fourwing saltbush on unprepared seedbeds could be feasible under certain conditions. For example, many ranges in the Southwest support a satisfactory cover of herbaceous plants but no browse. On such ranges, drilling into the undisturbed herbaceous cover, particularly if it is weakened due to drought as in the Monica study, might result in a fair stand of browse.

Transplanting

Cassady and Glendening (1940) recommended transplanting fourwing saltbush seedlings during the rainy season. Plummer et al. (1966) reported seedlings, nursery stock, or wildlings can be transplanted easily early in the spring. Burnham and Johnson (1950), however, reported their attempts to transplant seedlings to the field in northeastern New Mexico have been discouraging. McMillan (1960) considered transplanting feasible where only a few plants are wanted; he recommended seeding as more practical for range rehabilitation in the semiarid parts of California.

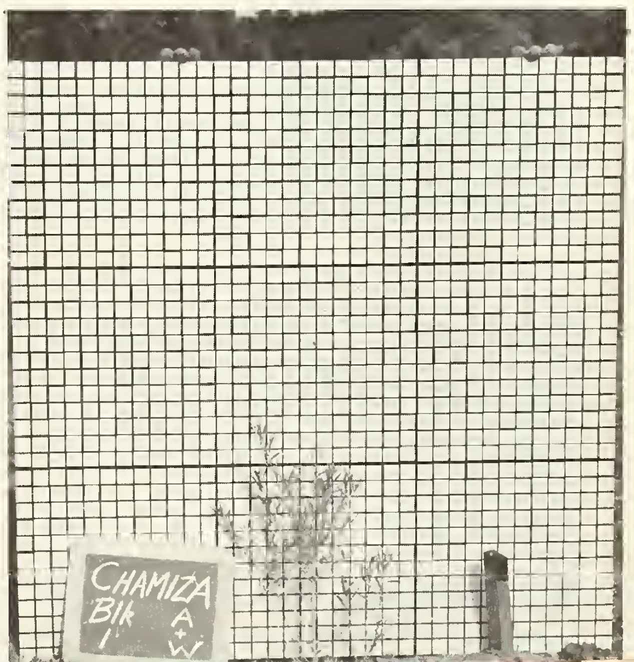
In our studies, growth of plants differed according to source of seed. At the Wingate site, for example, transplants from certain sources of seed planted in August 1966 grew taller than other sources. All plants were 12 inches tall when transplanted. Differences in height as of October 18, 1968 are due to growth or "die back":

Seed source	Average height (Inches)
Lamy, New Mexico	17.8
Corona, New Mexico	16.2
Delta, Colorado	15.3
Gran Quivira, New Mexico	14.6
Isleta, New Mexico	14.4
Keams Canyon, Arizona	12.6
Datil, New Mexico	12.2
Lovington, New Mexico	10.2
Lordsburg, New Mexico	8.4
Safford, Arizona	8.1
Ft. Thomas, Arizona	7.8

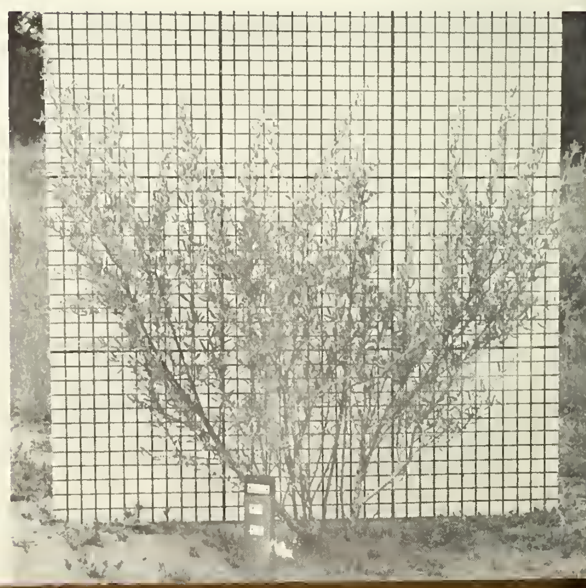
Bare-root stock may be successfully established if soil moisture is adequate (fig. 29). One-year-old

Figure 29.--Bare-root stock may be successfully established if soil moisture is adequate:

6 months after transplanting.



2.5 years after transplanting.



plants from the Los Lunas Plant Materials Center were planted as bare-root stock at the Corona site in April 1962. Soil moisture was near field capacity, and temperatures were cool at the time of planting. Percent survival was higher where competing blue grama was eliminated:

	Survival	
	Grass competition	No competition
	(Percent)	
1963	75	88
1964	62	82
1965	56	68
1966	44	68

Decreases in percent survival reflect changes in site conditions and rabbit and deer browsing. Competition from grass gradually increased on all areas, particularly on the "no competition" areas, as no measures were taken to control grass that became reestablished.

Survival from transplants in our New Mexico studies has been high at all sites. Except where rabbits or rodents destroyed plants, survival 2 and 3 years after planting has ranged from 50 to 100 percent.

Survival has varied according to age and size of seedlings. Seedlings planted in August 1964 at the QRA site in competition with native blue grama showed the following survival and growth in September 1967:

When transplanted		September 1967	
Age (Weeks)	Average height (Inches)	Survival (Percent)	Average height (Inches)
4	2.7	55	8.8
8	6.3	100	10.7
14	11.9	100	15.5

Apparently, seedlings should be at least 8 weeks old and 6 inches tall for transplanting.

Vigor and growth of transplants appear to vary with kind of site preparation. Seedlings 5 to 6 inches tall transplanted in July 1966 measured as follows in March 1967:

	Average height (Inches)
No site preparation	7.8
Shallow furrows	7.8
Large pits (5 inches deep)	12.5
Plastic mulch squares	14.0

Plants grew best on sites prepared by methods that eliminate much of the competing vegetation and provide additional moisture.

Time to Seed

Hervey (1955) reported spring seedings were more successful than fall seedings in Colorado. Plummer et al. (1966) obtained the best stands in Utah from winter planting; seeds were broadcast on snow and covered by chaining in late winter or early spring. According to Wilson (1928) seedlings emerge whenever the soil remains moist for several days during the fall, winter, or early spring. Bridges (1942) recommended seeding from September to January.

Our trials conducted over a 3-year period at two sites in New Mexico showed spring and midsummer seedings were more successful than early or late fall seedings (Springfield and Housley 1952). Results of these trials indicated success of seeding depends largely on the amount and seasonal distribution of precipitation during the period when temperatures are favorable for germination and establishment; these conditions prevail most consistently in spring and midsummer in New Mexico.

Other studies conducted for 3 years at the QRA site showed large differences in seedling establishment from year to year and from season to season (table 23). In general, precipitation patterns explain the differences in stands resulting from the nine dates of seeding.

The October 16, 1964 seeding produced a stand of about one plant per 5 feet of row. Since no seedlings were found in late April, the seedlings must have emerged in May or June. Precipitation for the May-June period totaled 3.80 inches, well above average for the area. This precipitation explains the development of seedling stands from the April 28, 1965 seeding as well as for the October 16, 1964 seeding. The July 1, 1965 seeding was slow in developing. No seedlings were

Table 23.--Emergence and survival of fourwing saltbush seedlings from nine dates of seeding at the QRA site, 1964-67

Date of seeding	Seedlings			Precipitation		
	Maximum emergence		Survival on October 28, 1968	Between dates of seeding	1 month after seeding	2 months after seeding
	Date	Number per foot of row		- - -	Inches - - -	
1964:						
October 16	July 1, 1965	0.22	0.17	3.82	([1])	([1])
1965:						
April 28	July 1, 1965	.56	.50	3.80	1.52	3.80
July 1	September 15, 1965	.50	.33	5.89	1.04	2.67
September 29	November 2, 1965	1.33	0	5.14	2.35	([1])
1966:						
March 30	--	0	0	2.17	.19	1.12
July 1	--	0	0	6.77	1.38	4.49
October 11	March 17, 1967	3.38	1.11	2.08	([1])	([1])
1967:						
April 6	August 18, 1967	2.67	.39	3.26	.04	1.11
July 18	August 18, 1967	4.89	1.94	[2]4.43	3.18	3.81

[1]Insufficient data.
[2]To October 13, 1967.

visible August 18, but a fair stand of very small, newly emerged seedlings was found September 15. These seedlings, only 1 inch tall, were present November 2, 1965, but by June 1966, about 20 percent of them had died.

No seedlings became established from three dates of seeding: September 29, 1965, March 30, 1966, and July 1, 1966. Seedlings emerged from the September 29, 1965 seeding when 2.35 inches of precipitation fell during the month of October, but none of these seedlings survived through winter. No emergence was ever observed for the March 30 and July 1, 1966 seedings, despite what seemed to be relatively favorable moisture conditions. Presumably the intervals between effective rains were such that germination was initiated and the seedlings began developing but died before they emerged.

By contrast, the three most recent dates of seeding—October 11, 1966, April 6, 1967, and July 18, 1967—resulted in excellent seedling emergence. The 6 months following the October 11, 1966 seeding were unusuallydry—only 2.08 inches precipitation at the study site. Examination of weather records at the Santa Fe Airport, 4 miles from the study site, showed 1.05 inches fell in March, 0.43 on March 20, just 10 days before seedlings were observed emerging. Though the top 0.5 inch of soil was dry March 30, excavation revealed the seedlings were rooted in moist soil. Nearly two-thirds of these seedlings died during the next 2 months when precipitation totaled only 1.11 inches. Counts made March 30, 1967 showed 3.4 seedlings per foot compared with 1.3 per foot on June 27, 1967. Most of the seedlings alive in late June 1967 survived through October 1968. The July 18, 1967 seedings were benefited by abundant, well-spaced rains; seedling emergence and establishment were exceptionally high.

April and July seedings were far more successful than October seedings at the Monica site (table 24). Seedings with seeds collected at Taos and at Lamy were made on sites prepared three ways in blue grama sod. The number of seedlings found in October 1967 reflects the combined effects of delayed emergence and seedling mortality. Delay in seedling emergence was especially apparent on plots seeded in October 1964. Seedling mortality averaged about 50 percent for the April and July seedings. Seedling establishment averaged highest from seeding in April for the Taos seed, but from seeding in July for the Lamy seed. Perhaps the

Table 24.--Establishment of fourwing saltbush seedlings in relation to three seeding dates at the Monica site (seed collected at Taos and Lamy)

Date of observation	Precipitation during interval	Seedling establishment[1] by time of seeding and seed source					
		October 12, 1964		April 1, 1965		July 7, 1965	
		Taos	Lamy	Taos	Lamy	Taos	Lamy
	Inches	- - - - Number per foot of row - - - -					
1965:							
April 1	1.58	0	0	--	--	--	--
August 10	8.68	0	0	0.9	1.3	0.4	1.9
November 17	4.44	0	.1	.6	.8	.2	1.2
1966:							
August 26	9.37	.1	.4	.4	.8	.2	1.0
October 18	2.12	.1	.3	.4	.8	.2	.9
October 23	12.44	.1	.2	.4	.6	.2	.9

[1]Average for rototilled and chemically sprayed seedbeds.

Taos seed, which originated from a more northerly area, responds better to cool temperatures than the Lamy seed.

Precipitation is more dependable during the period July 12 to August 23 for most areas in New Mexico.

Seeding Rate

Rate of seeding will depend on the size and quality of the seed. Various seeding rates have been recommended. Wilson (1928) recommended 8 to 10 pounds per acre for winged seeds. Later he recommended 14 to 16 pounds per acre (Wilson 1931). Van Dersal (1938) also recommended 14 to 16 pounds per acre. Bridges (1942) suggested 10 to 15 pounds, and the U. S. Forest Service (1948), 8 to 10 pounds per acre. Springfield and Housley (1952) recommended three viable seeds per square foot. Plummer et al. (1966) reported good stands from spot seeding by hand at the rate of 5 pounds per acre.

Based on recent findings concerning seed fill and number of seeds per pound, seeding rates of 4 to 8 pounds per acre for de-winged seed or 8 to 15 pounds per acre for winged seed should be adequate.

Adaptability

Fourwing saltbush survived and grew for 16 years at five representative pinyon-juniper sites in New Mexico (Springfield 1965). Plots seeded in 1946 were evaluated periodically until 1962. Stand ratings in 1962 for two sources or geographic strains were as follows:

Study site	Rating: Las Cruces source	Rating: Taos source
Corona	Fair	Fair
Fort Bayard	Poor	Good
Glorieta Mesa	--	Good
Monica	Excellent	Excellent
Taos Junction	Poor	Good

At the Corona site, the stands were damaged by rodents and deer.

Stands produced from seed collected near Taos generally rated higher than stands from seed collected near Las Cruces (fig. 30). Adaptability ratings of 14-year-old stands at Tres Piedras and Costilla in New Mexico indicate that probably 8,500 feet represents the upper elevational limit of adaptability.

Figure 30.--These fourwing saltbush plants at the Monica site were established by planting seed from near Taos in 1946. These 14-year-old plants have withstood the rigors of the climate and are considered well adapted. Plants from seed collected near Taos generally have proved adapted to more sites than plants from seed collected near Las Cruces.

More recently, container-grown plants have been planted at the various sites to test their adaptability to different climates and soils. The plants were grown from seed collected at a number of sites in Arizona and New Mexico. Plants were 1 year old at the time of transplanting.

Though the plants have been tested only a few years, indications are that certain geographic sources, which may or may not represent distinct ecotype strains, are better adapted to a given area. For example, plants from Chevelon, Arizona, were definitely taller and more vigorous than plants from other sources after 4 years at our QRA site:

Source	Average height (Inches)	Average vigor[1]
Arizona:		
Chevelon	26.5	2.5
Benson	11.6	1.7
New Mexico:		
Los Lunas	19.0	2.1
Moriarity	15.2	2.0
Magdalena	15.1	1.9
Datil	15.0	1.8
Corona	12.6	1.7
Bernalillo	10.7	1.6
Hatch	8.8	1.5
Glenwood	7.6	1.4

[1]1 = poor; 2 = fair; 3 = good.

Poorest in growth and vigor were the plants from Glenwood, New Mexico. Another example is provided by plants at our Silver Hill site, planted in August 1965. Of 11 ecotypic strains, these four New Mexico sources appear best adapted, based on measurements made October 25, 1968:

	Average height (Inches)	Average vigor[1]
Isleta	17.9	2.1
Gran Quivira	15.8	1.8
Deming	13.4	1.8
Placitas	9.6	1.5

[1]1 = poor; 2 = fair; 3 = good.

Wilson (1931) reported seed from Las Cruces did not give satisfactory results when planted near Galisteo, 220 miles north. But seed from Estancia, which is only 40 miles south of Galisteo, produced shrubs that grew well near Galisteo.

As a general rule, seed for revegetation should be obtained from nearby or north of the planting site.

Insect and Animal Damage

Many successful seedings of fourwing saltbush have been damaged or destroyed by insects, rabbits, or rodents. Grasshoppers eat the cotyledons and stems of small seedlings, and some seedling stands have been completely destroyed. Rabbits and rodents also can severely damage or destroy seedling stands. Wilson (1928), Cassady and Glendening (1940), Bridges (1941), and Plummer et al. (1966) stressed the importance of controlling rabbits and rodents. Both cottontails and jackrabbits are very destructive to saltbush seedlings.

Tests were made to determine the effects of grasshoppers on seedling survival at the QRA site. These tests were conducted because evidence accu-

mulated in 1965 and 1966 indicated the death of many seedlings was due to grasshoppers, not drought. In March 1967, small wire cages were installed over selected groups of seedlings, and charts were drawn showing the position of each seedling inside and outside the cages. Comparisons between charts drawn March 7 and August 7 showed the following seedling mortality:

	Percent
Open to grasshoppers	57
Protected from grasshoppers	22

Further studies were made at the QRA site to determine how much damage grasshoppers, and rodents or rabbits, do to seedlings. In July 1967, seedlings 2 to 3 inches tall were transplanted to the site. One-third of the seedlings were protected from rodents or rabbits by wire cages, and another one-third were protected from grasshoppers (fig. 31). By November 3, 1967, rodents or rabbits had damaged half of the seedlings (table 25). Cottontails were responsible for most of the damage. Grasshoppers injured a higher percentage of seedlings than did rabbits, but the degree of injury to individual seedlings was less. Thus, grasshoppers ate portions of leaves of many seedlings but the dam-

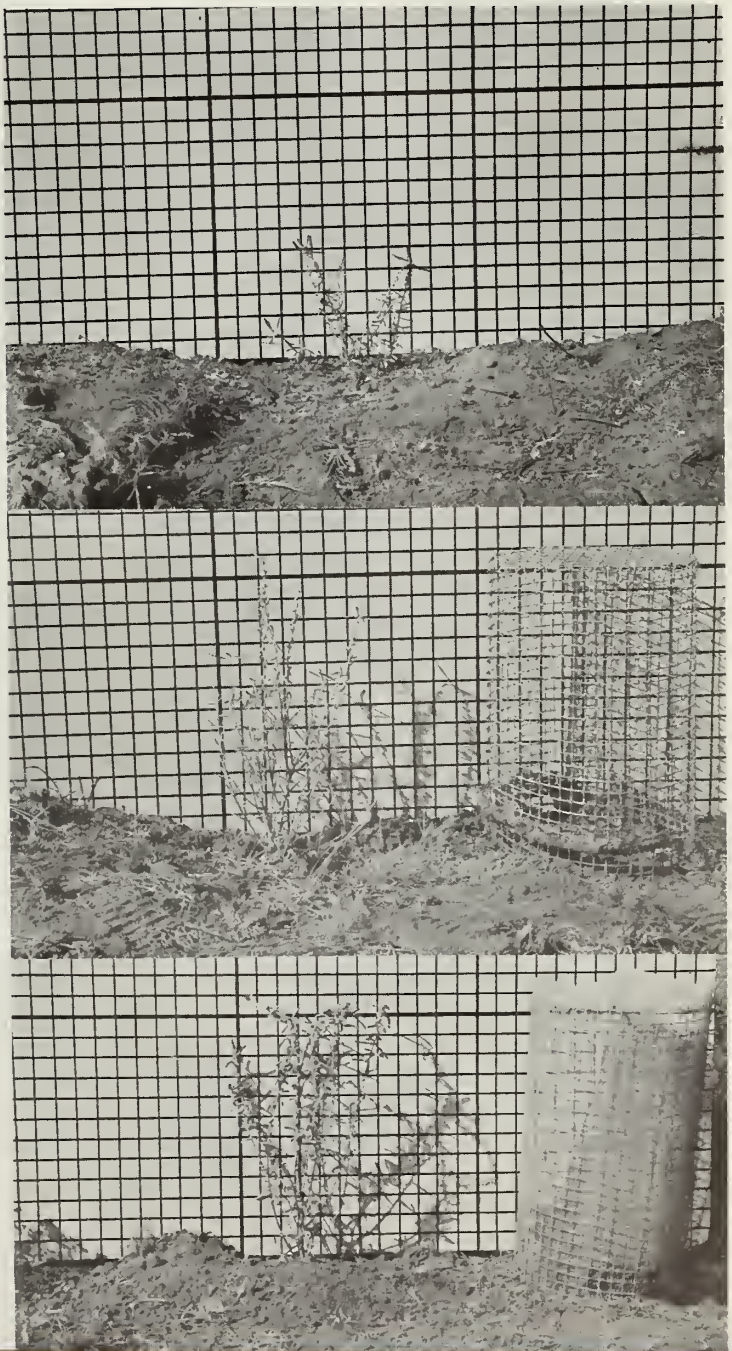


Figure 31.--Condition of fourwing saltbush plants 16 months after seedlings were transplanted to QRA site in July 1967:

Not protected (control).

Rodents and rabbits excluded.

Rodents, rabbits, and grasshoppers excluded.

Table 25.--Grasshopper, rodent, or rabbit damage to fourwing saltbush seedlings transplanted to QRA site, July 1967

Plot treatment and date observed, 1967	Plants damaged by--		Degree of damage[1]	
	Grasshoppers	Rodents, rabbits	Grasshoppers	Rodents, rabbits
	- - Percent - -			
Not protected (control):				
August 7	0	8	0	7.0
August 21	17	25	2.0	7.7
September 18	67	33	1.9	7.0
November 3	67	50	1.9	6.8
Rodents, rabbits excluded:				
August 7	8	0	2.0	0
August 21	25	0	2.0	0
September 18	92	0	1.6	0
November 3	92	0	1.6	0

[1] 1 to 2 = very light 5 to 6 = moderate
3 to 4 = light 7 to 8 = heavy

age was light. Rabbits, on the other hand, either heavily browsed a plant or completely ignored it; there was no evidence of light browsing by rabbits during the 4 months.

In 1968, grasshoppers were not numerous and inflicted practically no damage, but rabbits occasionally browsed the plants. Survival and height of the plants, as of November 4, 1968, were as follows:

	Average survival (Percent)	Average height (Inches)
Not protected (control)	67	9.9
Rodents, rabbits excluded	92	11.5
Rodents, rabbits, grasshoppers excluded	100	11.9

These results, coupled with observational evidence, indicate rodents or rabbits are more serious enemies of fourwing saltbush than are grasshoppers. When grasshoppers are numerous they may severely damage very small seedlings, especially in the cotyledon stage, but they have little effect on the growth of older seedlings. Rodents and rabbits, however, can be extremely destructive even to relatively large seedlings, although seedlings 8 to 12 inches tall seem less vulnerable.

Repellent treatment appeared partially effective in reducing rabbit browsing damage to seedlings on the QRA site. Plants 5 inches tall were planted in August 1966, and sprayed in November. Observations in March 1967 revealed plants treated with repellent (Arasan 42-S plus sticker) were taller and browsed less severely by rabbits:

	Average height (Inches)	Average browsing injury[1]
Not sprayed	4.7	1.7
Sprayed	8.7	.4

[1] 1 = low; 2 = medium; 3 = high.

Apparently the repellent remained effective through the winter months.

Browsing by deer during the winter and by rabbits throughout the year damaged 2-year-old plants at the Carona site. Spraying plants with a repellent (Arasan 42-S plus sticker) reduced the injury only slightly.

Mature plants of fourwing saltbush plants rarely are damaged by rabbits or rodents, but deer and livestock sometimes browse plants so closely that vigor is reduced. Mature plants also have been found damaged by insects. Two scale insects, one identified as the irregular wax scale (Cercoplastes irregularis Ckll.), and the other an ensign coccid (Orthezia annae Ckll.), reduce plant vigor and seed production. Galls are fairly common; one cause of these galls is a fly (Asphondylia atriplicis (Townsend)). These gall-makers in turn are para-

sitized by a wasp (Torymus capillaceous (Huber))[9] Another insect, an unidentified case bearer, has been observed to bore into seeds and destroy the embryo.

SUMMARY AND CONCLUSIONS

Fourwing saltbush, a valuable browse plant, is palatable and nutritious the year round; it promises to play an important role in range improvement throughout the Southwest. Studies were conducted to learn more about its requirements for germination and establishment.

Size of seed varies from site to site, plant to plant, and even on the same plant. Number of seeds per pound ranged from 7,800 to 54,900 for winged seed and from 13,200 to 76,800 for de-winged seed.

Usually only about half of the seeds can be expected to contain embryos, although seed fill varies according to place and year of collection. The larger seeds within a collection generally are better filled than the smaller seeds, and some collection sites consistently produce seeds with higher fill.

Seeds are easily collected when they are ripe in the fall. Because they remain on the bushes during the winter, the seeds may be harvested over a period of several months. Hand collection is the usual practice.

The seeds apparently undergo afterripening, which seems to be essentially complete within 10 months after collection in the fall.

Winged seeds are fully imbibed in 24 hours, de-winged seeds in 15 hours.

Germination usually is best at relatively low temperatures. The optimum temperature range appears to be from 55° to 75°. At temperatures less than 55°, germination is delayed and proceeds more slowly than in the optimum range. High temperatures, especially those exceeding 80°, tend to suppress germination.

Germination is decreased and delayed by increasing moisture stress; it is negligible at stresses approximating wilting percentage. Seeds germinated well even under a relatively high 7-atm. stress at 63°, which suggests moisture stress may be less important when temperatures are near optimum.

Light apparently is neither required for germination, nor does it inhibit germination when temperatures are near optimum. There are indications, however, that light may be needed at relatively high temperatures, and perhaps also for freshly collected seeds.

The seeds appear to be sensitive to deficient aeration.

Seed viability can be maintained under ordinary dry storage; refrigeration or other special storage conditions are not necessary. Viability varies with year of collection, although some plants consistently produce seeds of higher viability than others. Seeds retain their viability for many years; seeds from one lot lost only half their germinative energy in 16 years.

Various seed treatments have not consistently improved germination. De-winging the seed in a hammermill, an accepted practice, reduces bulk, facilitates handling and seeding, and hastens germination. Effects of scarification vary with the source of seed and seedcoat characteristics; thin-coated seeds were damaged whereas thick-coated seeds were benefited by very light scarification. None of several chemicals, including thiourea, citric acid, hydrogen peroxide, and sulfuric acid, proved effective for stimulating germination. Results from stratification were inconsistent; some seeds germinated better following 30 days of moist chilling, but most did not respond. No advantages were found from soaking or washing the seeds in water.

Seed viability can be determined by staining embryos with tetrazolium chloride. This is a quick test, the results of which are available in hours rather than in weeks.

Under nursery conditions, seedlings begin emerging within 6 to 10 days after the seeds are planted, provided moisture is adequate and temperatures are near optimum. Emergence usually is complete within 12 to 20 days. Seedling mortality sometimes is high, presumably due to seedborne or soilborne organisms. Contamination of seedlings by pathogens is not uncommon. Fungicidal treatment of seeds or soil, or both, has been partially effective in reducing seedling mortality.

Growth of plants in the nursery generally has been better in soils from representative sites than in horticultural mixes.

[9] *Insects identified through cooperation with the Insect Identification and Parasite Introduction Research Branch, U. S. Dep. Agr., Agr. Res. Serv., Beltsville, Md.*

De-winged seeds should not be planted more than an inch deep. Seedling emergence was greater and more rapid from 0.5 inch than from 1.5 or 2 inches.

Mulching usually improves seedling establishment. The application of straw, certain chemical mulch materials, or native grass generally resulted in greater seedling emergence and survival. Planting the seeds in moist soil and applying a mulch to delay moisture losses appears to be an effective seeding technique. Mulches that reduced afternoon temperatures were the most satisfactory for summer seeding.

Seedbed preparation probably is necessary to obtain good stands of fourwing saltbush by direct seeding. Although plants have been successfully established by drilling directly into drought-weakened blue grama sod, the resulting stands were much poorer than those on prepared seedbeds. Plowing is undoubtedly the best method of seedbed preparation where the native cover is composed mainly of undesirable plants. Where a remnant of desirable species exists, however, pitting or furrowing may be preferable.

Transplanting is an effective method of establishing stands, particularly on critical areas. Nursery-grown plants or wildlings can be readily transplanted in moist soil. Survival is high. Plants should be at least 6 inches tall for transplanting. Removal of competing vegetation from around the plant improves survival and growth.

Spring and midsummer seedings usually are more successful than fall seedings in the Southwest. Success of seeding depends largely on the amount and seasonal distribution of precipitation during the period when temperatures are favorable for germination and establishment.

Seeding rates of 4 to 8 pounds per acre for de-winged seed or 8 to 15 pounds per acre for winged seed should be adequate.

Long-term adaptability trials showed fourwing saltbush was adapted at several sites ranging in elevation from 6,300 to 7,500 feet. Plants grown from southern New Mexico seed generally were less well adapted than those from northern New Mexico seed. Both sources grew poorly at 8,500 feet. As a rule, seed for revegetation should be obtained from nearby or north of the planting site.

Control of rabbits and rodents, where they are numerous, is recommended. Stands of fourwing saltbush are especially susceptible to damage during the seedling stage. Repellents have partially prevented damage.

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COMMON AND BOTANICAL NAMES OF PLANTS MENTIONED

Grasses

Dropseed, sand	*Sporobolus cryptandrus* (Torr.) A. Gray
Galleta	*Hilaria jamesii* (Torr.) Benth.
Grama, blue	*Bouteloua gracilis* (H.B.K.) Lag.
Grama, sideoats	*Bouteloua curtipendula* (Michx.) Torr.
Muhly, ring	*Muhlenbergia torreyi* (Kunth) Hitchc.
Wheatgrass, western	*Agropyron smithii* Rydb.

Trees and Shrubs

Creosotebush, Coville	*Larrea tridentata* (DC.) Coville
Juniper, one-seed	*Juniperus monosperma* (Engelm.) Sarg.
Mountainmahogany, true	*Cercocarpus montanus* Raf.
Pinyon	*Pinus edulis* Engelm.
Sagebrush, big	*Artemisia tridentata* Nutt.
Winterfat, common	*Eurotia lanata* (Pursh) Moq.

Springfield, H. W.
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Seeds of fourwing saltbush remain viable many years under ordinary dry storage. Usually, only about half the seeds contain embryos. Viability is easily checked with tetrazolium chloride. After-ripening is complete in 10 months. De-winging the seeds facilitates handling and hastens germination. Seeds should be planted 0.5 to 1 inch deep during spring or summer; seedbed preparation is recommended. Mulching usually improves seedling establishment. Seeds are fully imbibed within 24 hours; optimum temperatures for germination are 55°F. to 75°F. Germination is decreased and delayed by increasing moisture stress. Transplants may be used effectively for critical areas.

Key words: Germination, establishment, fourwing saltbush, Atriplex canescens

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About The Forest Service. . . .

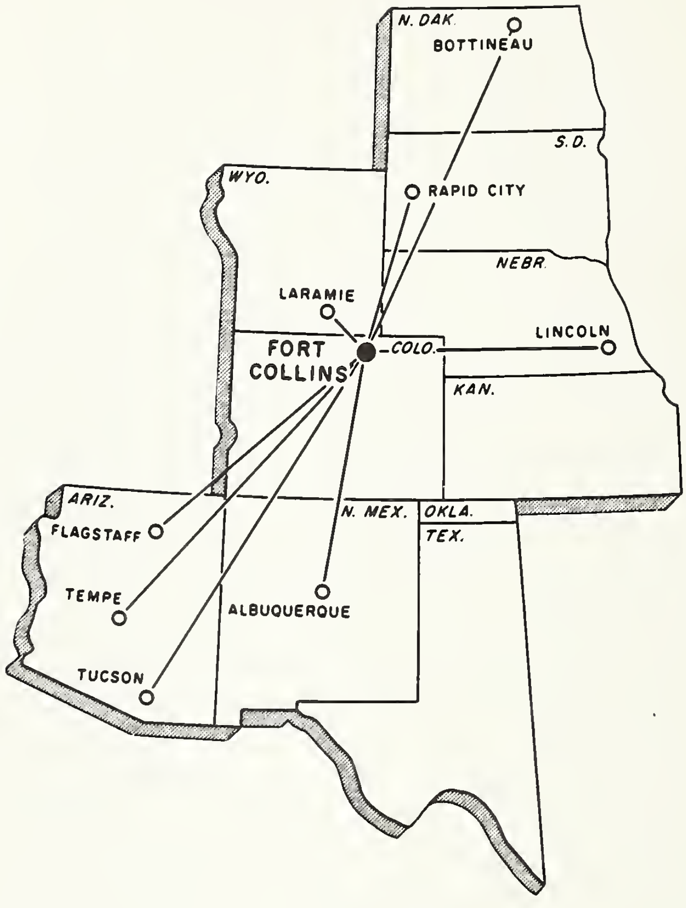
As our Nation grows, people expect and need more from their forests—more wood; more water, fish and wildlife; more recreation and natural beauty; more special forest products and forage. The Forest Service of the U. S. Department of Agriculture helps to fulfill these expectations and needs through three major activities:

- Conducting forest and range research at over 75 locations ranging from Puerto Rico to Alaska to Hawaii.
- Participating with all State forestry agencies in cooperative programs to protect, improve, and wisely use our Country's 395 million acres of State, local, and private forest lands.
- Managing and protecting the 187-million acre National Forest System.

The Forest Service does this by encouraging use of the new knowledge that research scientists develop; by setting an example in managing, under sustained yield, the National Forests and Grasslands for multiple use purposes; and by cooperating with all States and with private citizens in their efforts to achieve better management, protection, and use of forest resources.

Traditionally, Forest Service people have been active members of the communities and towns in which they live and work. They strive to secure for all, continuous benefits from the Country's forest resources.

For more than 60 years, the Forest Service has been serving the Nation as a leading natural resource conservation agency.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